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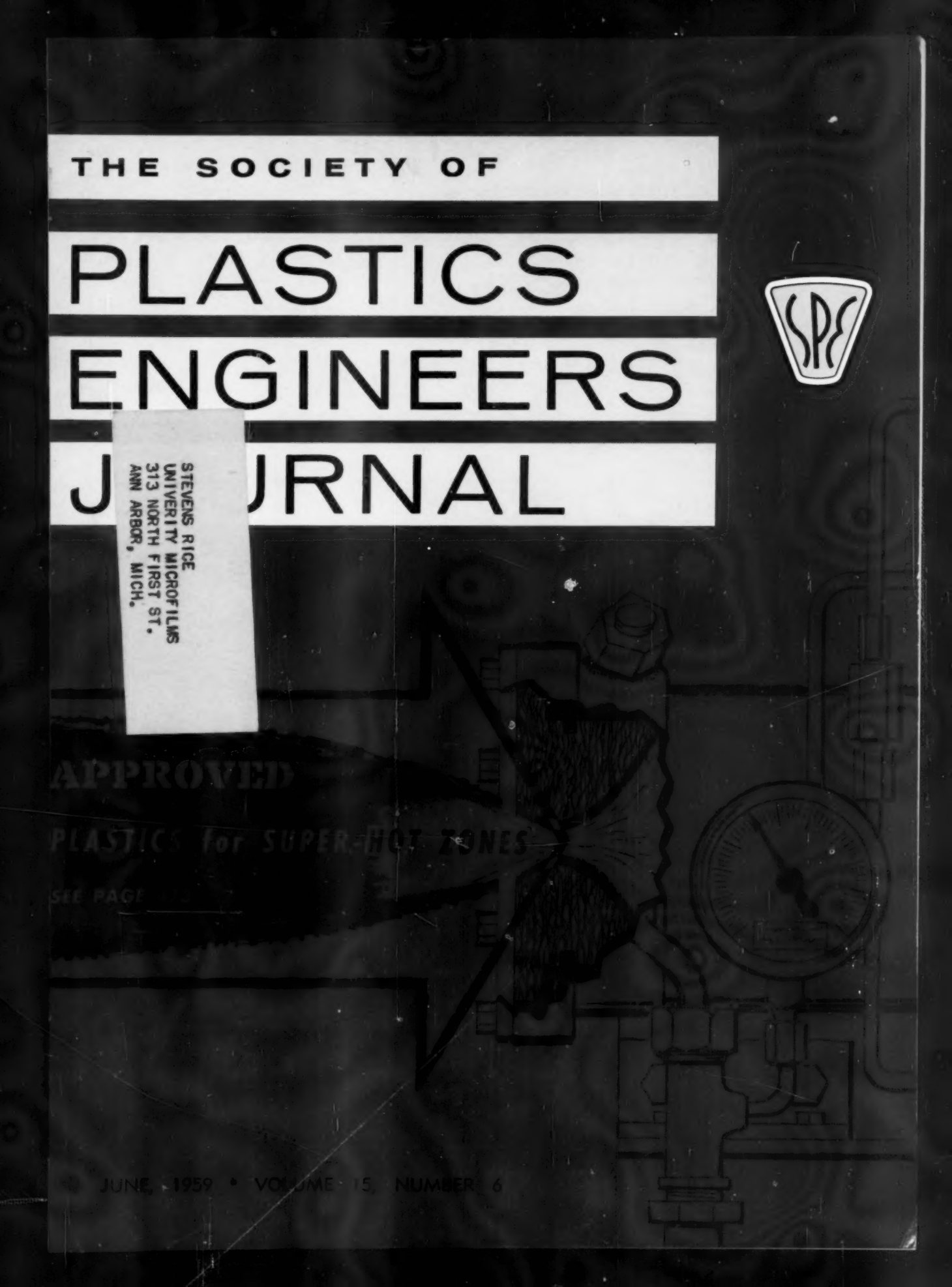

JUNE, 1959 • VOLUME 15, NUMBER 6

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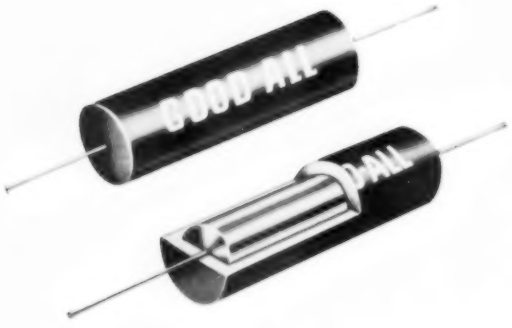

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Why? Because the excellent physical properties of Epon resins eliminate the need for conventional containers and housings. Size, weight, and complexity of components are reduced.

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As a result, in shops equipped with Hartig and one or more other makes, you will usually find Hartigs logging more production time. We will be glad to give you facts and figures on Hartig equipment for your operation.

Send for your copy

of the new illustrated booklet describing the line of Hartig Extruders and Matched Auxiliary Equipment.

HARTIG EXTRUDERS

Division of Midland-Ross Corporation
MOUNTAINSIDE, NEW JERSEY

Hartig 4½" extra long extruder
24:1 L/D, with sheeting die.
Effective Screw Length: 108¼"
Nominal Capacity: 300-310 lbs./Hr.
Barrel Heat: 19 bands, 3200 W ea.
Control Zones: barrel 5, die 1
Temperature Controls: 6 (proportioning)
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Floor Dimensions: 203" x 82"
Weight (approx.): 8500 lbs.
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Just announced . . . light-stable polystyrene hits new high in resistance to yellowing!

STYRON® 672 and STYRON 673

VERELITE

The introduction of Styron 672 Verelite and Styron 673 Verelite heralds a significant new advance in fluorescent lighting fixture materials. Both are new, light-stabilized formulations developed by Dow for such applications as light grids, diffusers, and folding curtains.

These new polystyrenes have been fully tested and proved. They exceed the specification adopted jointly by the National Electrical Manufacturers Association, Illumination Engineering Society and Society of Plastics Engineers. In light stability tests, for example, they exhibited a yellowing factor of 2.3 after 500 hours, well within the allowable maximum of 15. General purpose polystyrene formulations reach 15 after only 393 hours of exposure. Thus the non-yellowing characteristics of the Verelite formulations make them an excellent material for fluorescent applications.

Both Styron 672 Verelite, the molding formulation, and Styron 673 for extrusion are now available in a wide range of granulations to meet varying requirements. For more information, return the handy coupon below for technical data and prices.

The addition of these two new polystyrenes brings the already extensive line of Styron formulations to a total of 15. Another milestone for industry's fastest growing group of polystyrene formulations.

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Plastics Sales Department 2115EX6
Midland, Michigan

Please send me technical information and price schedule on Styron 672 Verelite and Styron 673 Verelite.

Name_____ Position_____

Firm_____

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City_____ Zone____ State_____

News about

B.F.Goodrich Chemical *raw materials*

Fume diffusers are fabricated by Electro-Chemical Products Company, Cleveland, Ohio, of sheets of rigid Geon made by Seiberling Rubber Company, Newcomerstown, Ohio. B.F.Goodrich Chemical Company supplies the Geon polyvinyl material only.

FUME DIFFUSERS TOOK A LICKING FROM CORROSION

. . . till the cones were made from GEON

THESE cones of Geon rigid vinyl show how you can solve corrosion problems. They are used to diffuse hydrofluoric and chromic acid fumes in a chemical plant, where cones of metal and other plastic were tried first.

Geon rigid vinyl solves corrosion problems—because it withstands acids, oils and many hydrocarbon chemicals. Geon also provides for accuracy in fabrication. For example, the sheet of rigid Geon from which these cones were made was machined to extremely close tolerance—.003 inches for the slots—to give the cones the exact design for most efficient fume dispersion.

Products of versatile Geon polyvinyl materials can be made in rigid form, rotationally cast, slush molded, calendered, extruded or blown into foam form. Applications range from solving all types of corrosion problems from piping to ductwork, to coatings for paper, metal and other materials.

For information on Geon polyvinyl raw materials, write Dept. AJ-2, B.F.Goodrich Chemical Company, 3135 Euclid Avenue, Cleveland 15, Ohio. Cable address: Goodchemco. In Canada: Kitchener, Ontario.

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Society of Plastics Engineers Journal

65 Prospect Street, Stamford, Connecticut

VOL. 15, NO. 6, JUNE 1959

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1 Year	$ 6.00	1 Year	$10.00
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*Single Issue	.65	*Single Issue	1.50

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● The SPE Journal is Published at 215 Canal St., Manchester, N.H. Address changes, undeliverable copies and orders for subscriptions should be sent to 65 Prospect St., Stamford, Conn.

● Application for transfer of second-class mail privileges from Orange, Connecticut, to Manchester, New Hampshire, pending.

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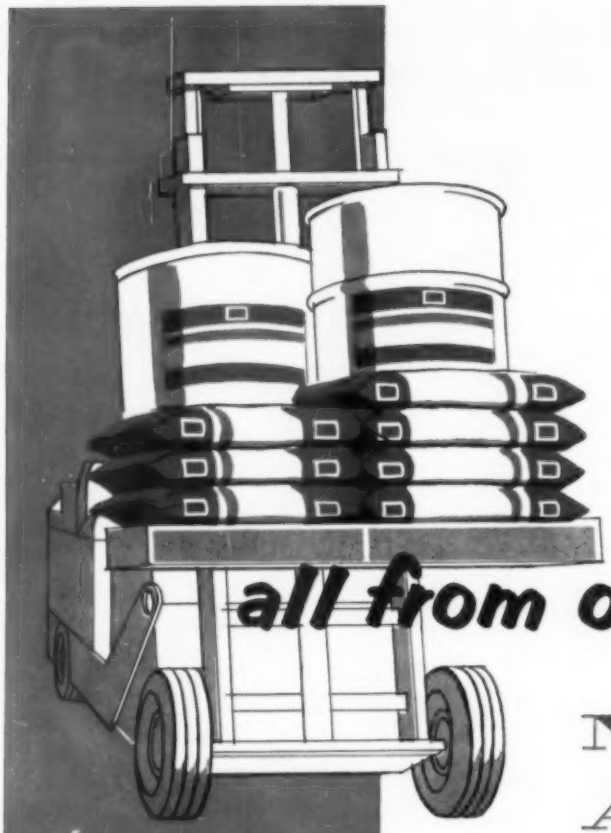

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An international scientific and educational organization of more than 7,000 individual members devoted to the development and dissemination of technical information in the fields of research, design, development, production and utilization of plastics materials and products. The Society is incorporated under the laws of the State of Michigan.

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Charles E. Rhine

Editor

EDITOR'S NOTEBOOK

DON'T "SHORT-CHANGE" YOUR SOCIETY

Each year, when dues invoices are sent out to the Membership, our apparent Membership shows a sudden tremendous decrease due to the fact that many members fail to take immediate action on this payment. The National Office has no recourse but to list these members as delinquents. You will be astonished, as I was, to learn that at times we have listed nearly 1,000 persons as delinquents. This represents almost 1/7th of our entire Membership! I am convinced that 7/8ths of these people have failed to take action due to vacations, forgetfulness and similar causes.

As your National Membership Chairman, I appeal to each individual in the Society to take prompt action on this invoice when it first reaches you. Help me fulfill my boast to the President that our Membership is sensitive to the changing needs of the Society.

J. R. Lampman
National Membership Chairman

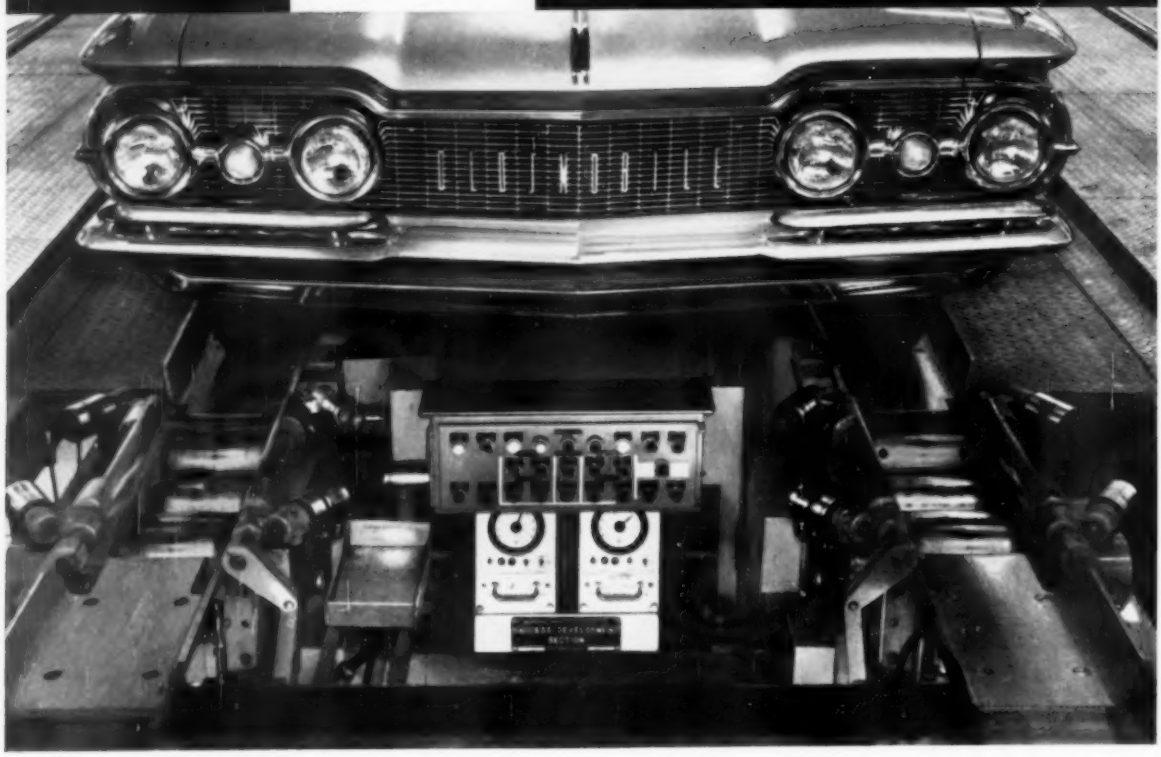
PAGEI Needs You

All members interested in a Task Group on Molding and Coating (this could include Fluidized Bed Methods) in the Professional Activities Group on Electrical Insulation (PAGEI) are urged to contact:

George F. Chadwick
Speer Carbon Company
Research Laboratory
Packard Rd. & 47th Street
Niagara Falls, New York

Your comments and suggestions will help determine the future of this group.

The Inquiring Mind at Oldsmobile



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OLDSMOBILE "TOES THE MARK" ... ELECTRONICALLY!

Oldsmobile Engineering Leadership sets the industry pace with a unique electronic wheel alignment device that dynamically computes "toe-in" measurements for precision steering and handling.

Handling and steering ease depend upon precise, minute measurement and control of front wheel alignment. Because wheels have a tendency to "toe-out" when in motion, they must be adjusted for a slight amount of "toe-in" to eliminate "wheel fight", wander and undue tire wear.

To meet the requirement of rapid, yet extremely accurate measurements on the production line, Oldsmobile engineers developed an electronic computor—a *linear-differential-variable transformer*—that dynamically and accurately measures the average amount of toe-in within .030 inches. As the car is brought into position, the wheels are rotated by rollers to simulate actual driving conditions and to eliminate errors caused by variations in tire run-out. By watching the visual gauges, an operator can quickly make the necessary adjustments to the steering linkage.

By using the most up-to-date electronic measuring techniques in engineering and manufacturing, Oldsmobile is able to offer safe, accurate steering and handling . . . a controlled, comfortable ride. Visit your local Oldsmobile Quality Dealer, take a ride in a '59 Oldsmobile and see why it's the value leader of its class!

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U.S.I. POLYETHYLENE NEWS

A series for plastics and packaging executives by the makers of PETROTHENE® polyethylene resins

JUNE, 1959 — U.S. Industrial Chemicals Co., Division of National Distillers and Chemical Corporation — 99 Park Ave., N.Y. 16, N.Y.

Packaging Notes

Polyethylene pouch in a carton is being used to package frozen berries and fruits packed in syrup or sugar. The heat-sealed pouch is made of polyethylene-coated paper. The polyethylene coating holds liquids inside the pouch even when fruit is thawed. A tear string is built into the pouch for easy opening. A carton and overwrap complete the package.

The new pack reportedly offers substantial savings in packaging costs and labeling versatility.

Heat sealable multiwall bag features staggered plies at the open end, leaving polyethylene-coated inner ply exposed for direct heat sealing. After sealing, adhesive is applied to the tops of the outer plies. The entire lip is folded over and pasted to the outside of the bag. The sealing machine then adds a strip of gummed tape across the lip. The new coated bags are said to be especially suitable for packaging hygroscopic, deliquescent, corrosive and semiliquid products.

New bag sealer closes open-end shipping sacks with a polyethylene-coated kraft paper tape. The machine caps a 2.5 inch wide tape over the open end of flat tube bags by means of heat and pressure. The molten polyethylene seals stitching perforations, making a tight, moisture-resistant seal. The sealer operates at production line speeds and is said to cut costs over conventional wax sealing. Taped bags are expected to be used soon for shipping a wide range of chemicals and fertilizer materials.

U.S.I. Appoints Two

Ralph M. Knight

William H. Rader

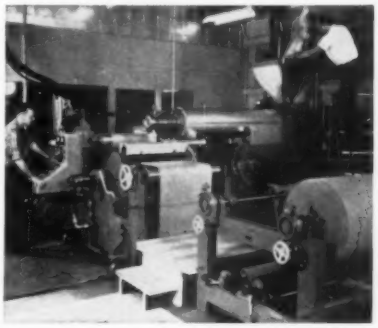
Ralph M. Knight has been named Manager of Polymer Planning and Applications by U.S.I. Mr. Knight will be responsible for planning and co-ordination of U.S.I.'s polymer development program. Mr. Knight previously has served U.S.I. in various polyethylene production capacities.

William H. Rader has been appointed PETROTHENE Polyethylene Production Manager. Mr. Rader has been Assistant Production Manager, and before that was in charge of polyethylene resin development programs at U.S.I.'s Tuscola plant.

Polyethylene-coated Milk Cartons Ready To Capture Volume

Leakproof Cartons Finding Favor with Retailers and Public

Polyethylene-coated milk containers are appearing on the market in selected areas and promise to take over a large share of the market now held by wax coated cartons. Although some machinery and production problems remain to be solved, the polyethylene-coated cartons have met with a favorable response with consumers and retail outlets.



The board coating machine above, located in U.S.I.'s Polymer Research Laboratory in Tuscola, runs at speeds equal to or greater than commercial equipment, duplicates the latter in everything but width.

Chief advantage of the polyethylene containers for both retailers and public is that the polyethylene cartons are virtually leakproof. Leakage of wax coated cartons has been a major problem. Polyethylene coatings not only provide stronger seals but also are more flexible at low temperatures and do not flake off as does wax. Polyethylene coated cartons are also scuff-resistant and may be printed easily.

Two Types Already on Market

Two types of containers are actually in use: a tetrahedron-shaped carton holding a pint or less, and a conventionally shaped full quart container. Initial use of the new polyethylene-coated milk cartons has been by dairies whose distribution systems involve rough or repeated handling that tends to damage conventional containers. New advances in container fabricating machinery, however, are expected to extend the use of polyethylene containers into major dairy markets.

Film Producer Offers Packaging Machinery Guide

A producer of polyethylene-coated films has issued a manual of automatic film packaging machinery available to users of polyethylene film packaging. The manual gives specifications for leading machines and describes such capabilities as speed, type of film that can be used, and package sizes each machine can handle.

The manual also contains conversion tables for calculating the yield of different film and paper combinations.

U.S.I. Opens New Sales Office in San Francisco

U.S.I. has established a new sales office in San Francisco to keep pace with the needs of customers in central and northern California and the Pacific Northwest. The address of the new office is: U. S. Industrial Chemicals Co., 220 Montgomery Street, San Francisco 4, California. The telephone is EXbrook 7-3250.

The new office will be tied into U.S.I.'s automated communications system through Pacific Coast headquarters in Los Angeles.

U.S.I. To Feature Cast Film At London Plastics Show

Cast polyethylene film will be demonstrated to the international market for the first time at the U.S.I. exhibit in the International Plastics Exhibition to be held in London, June 17-27.

Side-weld bags of ultra-clear PETROTHENE cast film will be made in the U.S.I. booth. Cast film was first introduced to the American market by U.S.I. last year.

In London, U.S.I. will also show packaging films made from PETROTHENE resins. A special feature of the exhibit will be a demonstration of how polyethylene garment bags are used by commercial dry cleaners to speed up customer identification of garments and to protect garments after they leave the cleaning establishment.

DO YOU HAVE a new polyethylene packaging development you'd like the industry to know about? Make it routine to send your information on new developments to U.S.I. POLYETHYLENE NEWS.

Address the Editor,
U.S.I. POLYETHYLENE NEWS, U. S. Industrial Chemicals Co., Division of National Distillers and Chemical Corp., 99 Park Avenue, New York 16, N.Y.

Yes, it's polyethylene

When you add brilliant printability to the clarity, toughness, and other well-known advantages of polyethylene, you can offer your customers a packaging material that will work as a powerful merchandising tool for their products. Polyethylene film can be economically printed with clear, bright colors at high speeds and with sharp registration and good ink adhesion. Packages can be formed on automatic machinery — sealed by heat-sealing or with adhesives.

Opens New Packaging Film Markets

With package designs that combine sparkling, multi-colored printing with polyethylene film's clarity, you can open up new packaging and merchandising opportunities for your customers. Printed film is now being used for dry-cleaner garment bags, produce packaging, soft goods overwrap, dairy and meat packaging, laundered shirt packaging, and many other applications where visibility, eye-catching color, and protection can be combined in a single package to give maximum sales appeal to the product.

In supplying film for this growing market, keep in mind the special advantages of U.S.I. PETROTHENE® polyethylene resins: excellent drawdown properties . . . superior toughness/clarity ratio in finished film . . . wide selection of resins ideally suited for clear or printed packaging film. Contact your nearest U.S.I. sales office for information.

U.S.I. is helping to expand your polyethylene film market with ads, similar to this one, addressed to the produce, food, dry-cleaning, and other package-using industries. These ads are designed to pre-sell your potential customers on the sales appeal and other advantages of polyethylene film packaging. To receive reprints of this advertising as it appears, write:

U.S.I. INDUSTRIAL CHEMICALS CO.
Division of National Distillers and Chemical Corp.
99 Park Ave., New York 16, N.Y.
Branches in principal cities

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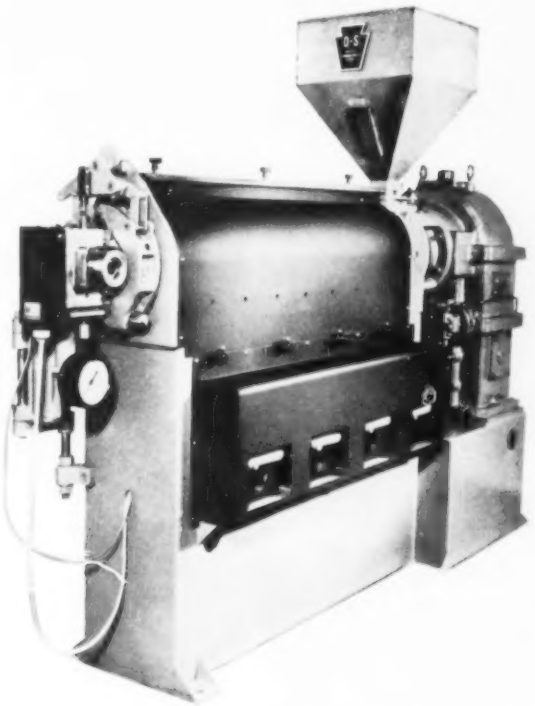
Anticipatory temperature controls boost work capacity of thermoplastic extruder

Exceptionally fast extruder warm-up and anticipatory control of temperatures in all heat zones by Wheelco Model 402 Capacitrols keeps this Davis-Standard Model 45T thermoplastic extruder producing at peak rates. Three or four cylinder heat zones (depending on length to diameter ratio) and a head heat zone are standard. Blowers and heaters are controlled from control panel which, like the extruder itself, is furnished prewired for maximum ease and economy of installation.

Model 402 Capacitrols are anticipatory time-proportioning controllers for applications where it is necessary to overcome system inertia. Tru-Line control produces all anticipatory action within the electronic circuit of the instrument and does not affect the measuring system in any way. It always indicates the correct value. Band width and cycle time are adjustable.

Both the control chassis and measuring system are of the plug-in type — as they are on all Wheelco 400 Series Capacitrols — simplifying inspection, adjustment and maintenance. Choice of control form is available on Wheelco 400 Series — enabling the best one to be selected for the specific job. More data available in Bulletin F-6485-1, "Capacitrols for the Plastics Industry." Write for your copy today.

Davis-Standard "Thermatic" extruder keeps temperatures on the button for all types of jobs with Wheelco Model 402 Capacitrols.



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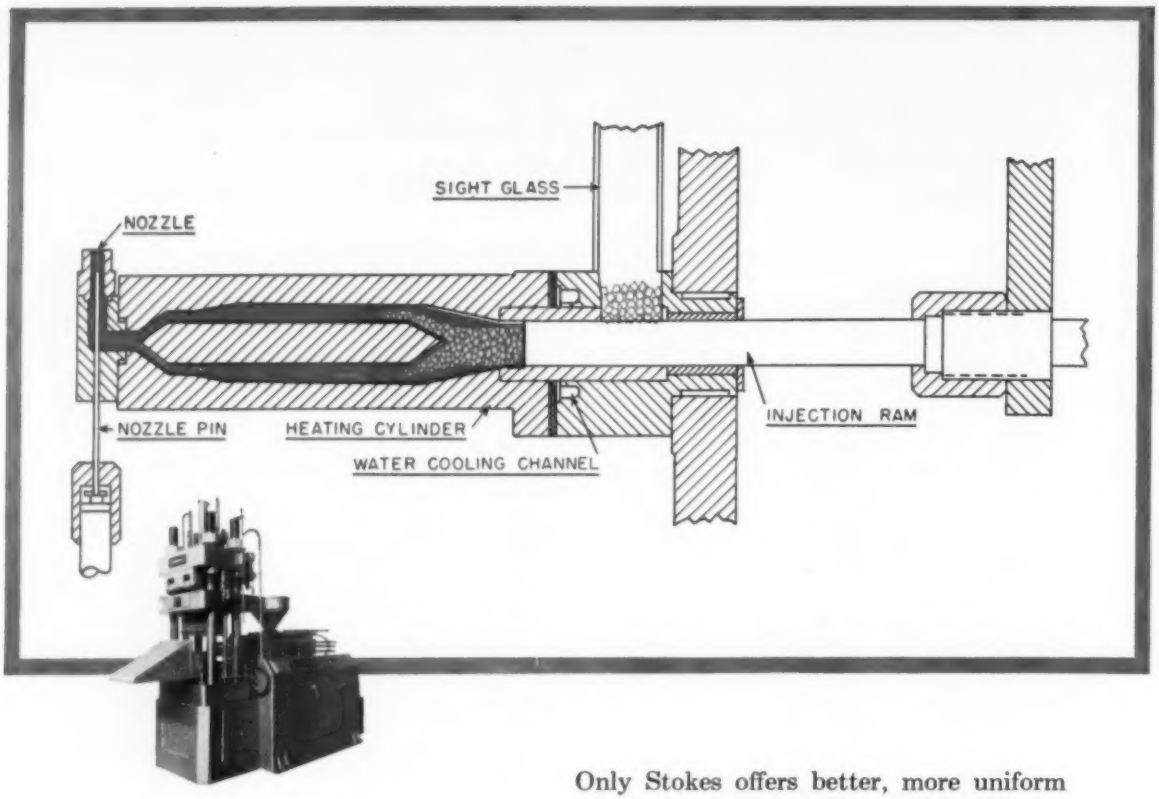

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Only Stokes offers better, more uniform parts and faster molding cycles with exclusive pressure pre-pack. Here's how it works: positive nozzle shutoff through action of the nozzle pin permits pressure pre-packing of the heating cylinder. All granular material is under pressure from the moment it enters the cylinder. Plasticizing capacity is increased, and injection time decreased as much as 75%.

Stokes pressure pre-pack is another feature that will help increase the quality of your product, and at the same time, reduce total operating costs. We'd like to give you all the facts on Stokes automatic injection molding . . . including *positive* ejection, *positive* nozzle shutoff, and *positive* pressure pre-pack. Why not get in touch with Stokes . . . today.

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TYPICAL PROPERTIES OF DPD-7365

Property	Value
Melt Index, g/10 min.	8
Density, g/cc at 23°C	0.935
Secant Modulus, psi	40,000
Tensile Strength, psi	1600
Elongation, %	210
Yield Strength, psi	1500
Brittle Temperature, °C	
50% OK	−70
80% OK	−60
Stress Cracking Resistance	
50% Failures, hours	>336
Mechanical Flex Life,	
No. of Flexes	200 000

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In selecting a plastics material for optimum use in a given design application, the best results can be obtained only by comparative analysis of *all* available related data.

QUALITY CONTROL DATA are often taken at a single point of measurement (at times this may be the only available datum for a given property) and may appear to be valid basis for selection. This can be misleading. In the case of two hypothetical plastic materials under consideration, Figure 1 shows how both exhibit the same degree of deflection under identical loads at a given temperature. Thus both would appear to be equally suitable for the job at hand based on this cursory analysis.

SCREENING DATA, developed through further investigation, now show that plastics "A" and "B" have totally dissimilar curves and properties. Figure 2 illustrates the curves generated when temperatures are plotted against increasing stress at a uniform measure of deflection. The misleading single point in Fig. 1 now appears only as the crossing point of the two dimensional curves. The difference in deflection temperature between the two samples is unmistakable.

DESIGN AND ENGINEERING DATA require further analysis. A three dimensional curve of deflection temperature, stress and allowable deflection is now plotted for each of the plastics. Figure 3 illustrates such a diagram for plastic material "A". Only in this way can we get a full picture of the material's potential value under possible changing conditions of use.

A great deal of experimental work is required to accumulate data sufficient to develop such three dimensional curves, but their ultimate application in design work makes them invaluable. Because of their inherent value to design engineers, Dow Plastics Technical Service Engineers are conducting extensive research in the gathering of multi-dimensional data on a number of Dow molding material formulations. This work is part of a continuing series of Plastiatrics studies aimed at assisting designers and engineers in the most effective selection of plastics materials.

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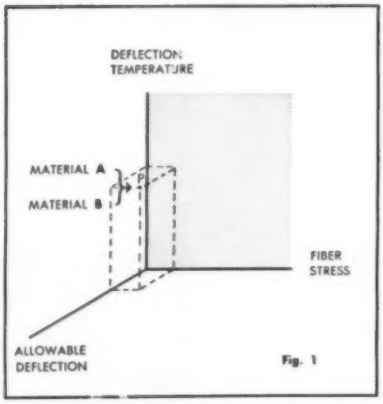

Fig. 1

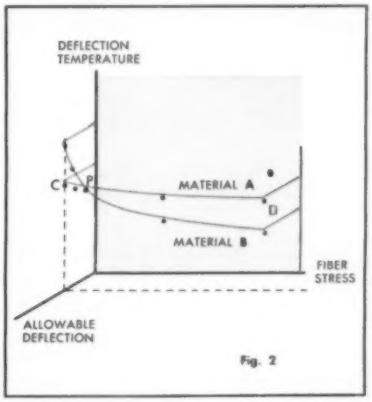

Fig. 2

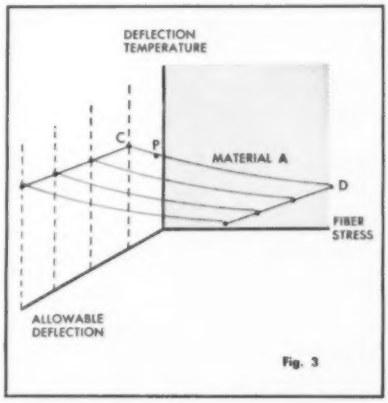

Fig. 3

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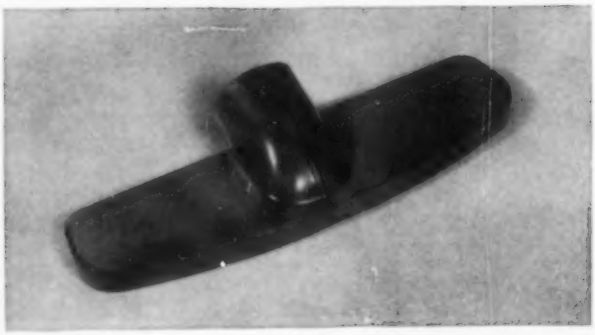

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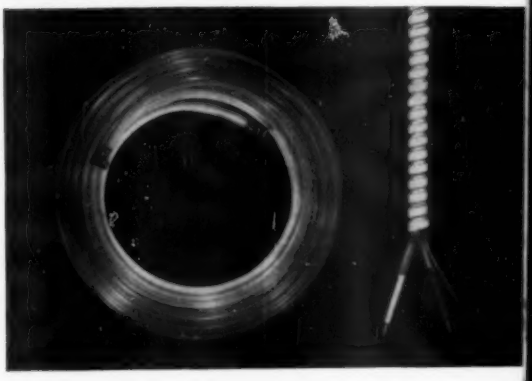

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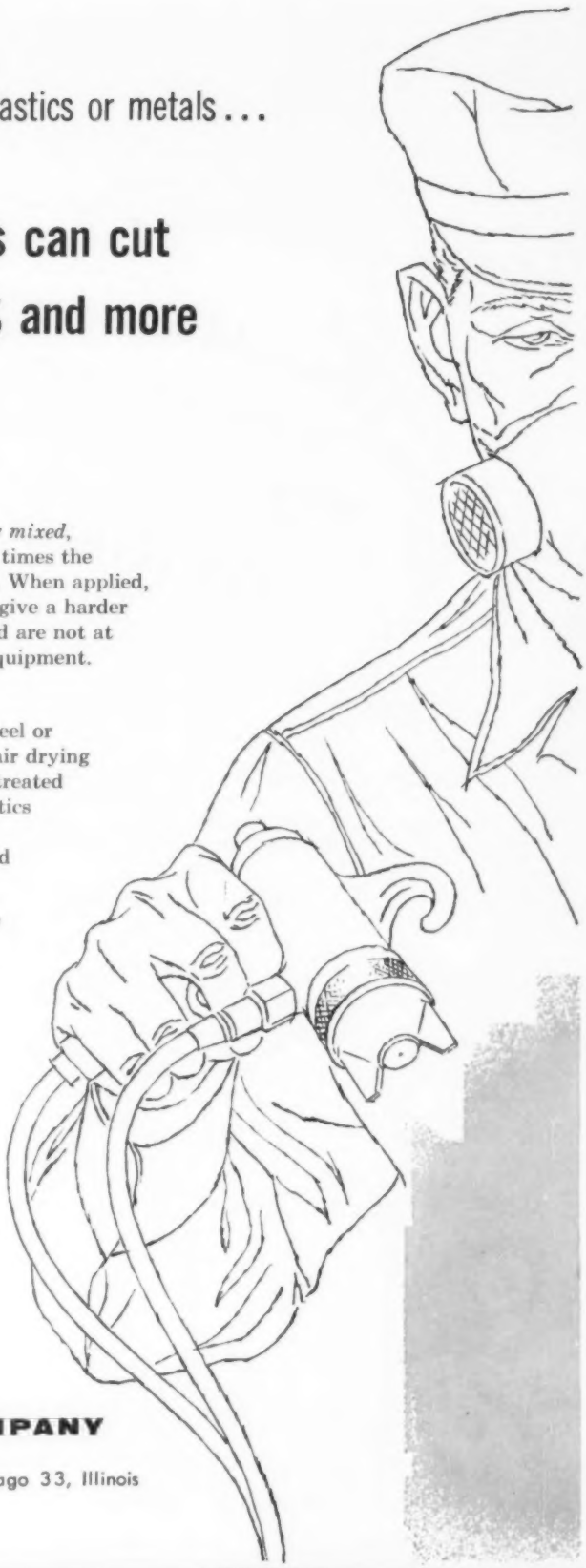

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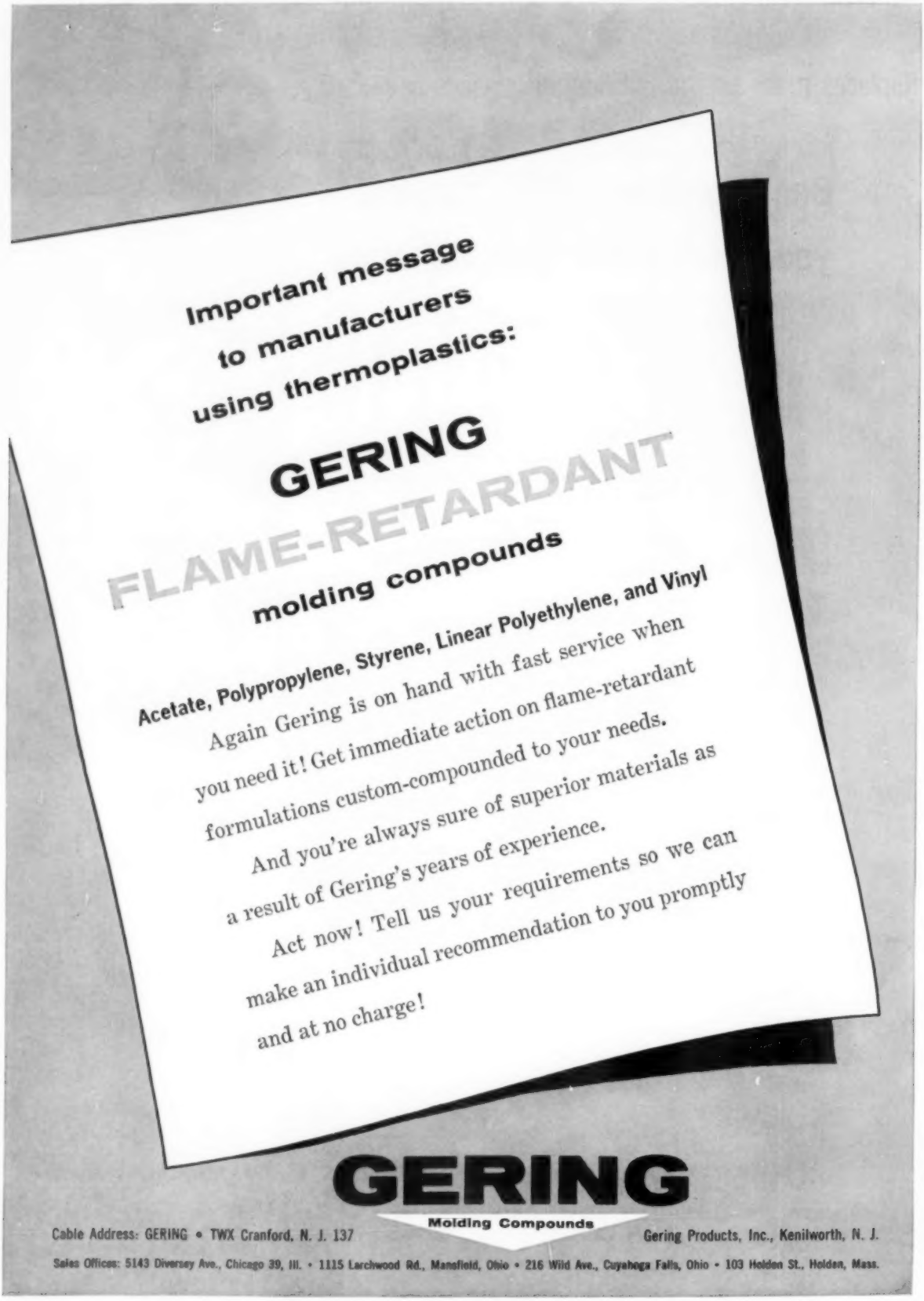
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PLASTICS ENGINEERS JOURNAL

Volume 15, Number 6, June, 1959

Reinforced Plastics for Rocket Motor Applications

George Epstein and J. C. Wilson

The Aerojet-General Corporation

Structural Plastics Division

WITH THE ADVANCEMENTS of technology in aerodynamics and propulsion, demands have been created for materials possessing unique thermal and mechanical properties. The escape and re-entry velocities of IRBM and ICBM missiles, satellites, etc. have created thermal shock and insulation requirements which only a few years ago were considered impossible to meet (Ref. 1).

Temperatures in excess of 10,000°F are considered normal requirements for a nose cone on a re-entry vehicle (Ref. 2). Temperatures of 4,000 to 6,000°F, accompanied by extremely high gas velocities, may be encountered in rocket nozzles and blast tubes (Ref. 3).

Even in the midst of these extreme service conditions, manned space vehicles and satellites will impose further requirements. Yet one can predict that manned vehicles returning from outer space, giant interplanetary missiles traveling light-years into the universe, and tactical satellites linking the planets will be constructed using some form of plastic materials.

Advantages of Reinforced Plastics for Rockets and Missiles

Current reports from various research establishments and all available information on successful missile launchings increase the prominence of plastics as a heat-resistant material for use in super-hot zones of missiles and rockets. The properties of reinforced plastics, particularly those employing glass, Refrasil*, quartz, nylon, and asbestos fibers as the reinforcing agent, appear to be well suited for the fabrication of certain components of rocket motor and missile systems. The high strength-to-weight ratio and relatively low thermal conductivity avail-

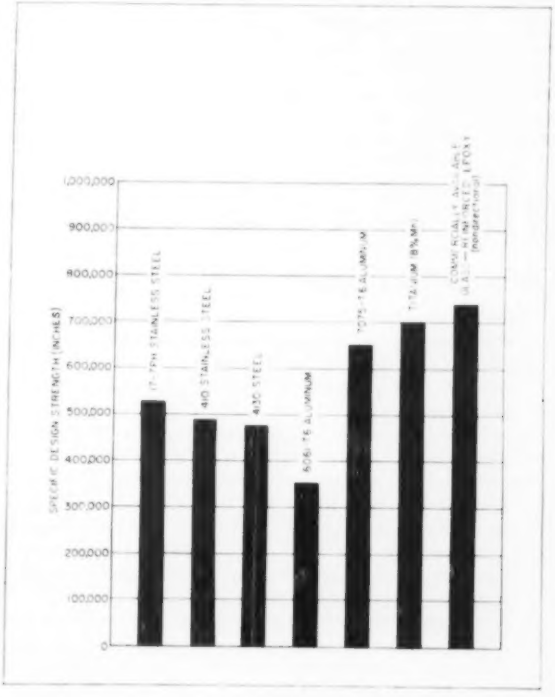

Figure 1. Specific design strength (design strength/density).

* Product of H. I. Thompson Fiber Glass Company, Los Angeles, Calif.

TABLE I

Thermal Conductivity of Various Construction Materials

Material	Btu/hr/sq ft/°F/in.
Reinforced Plastics*	0.75-1.25
Titanium	100-140
Stainless Steel	100-170
Aluminum	840-1560
Copper	2500

* Type 181 glass fabric impregnated with heat-resistant laminating resin—e.g., silicone, T.A.C.-polyester, and phenolic resins.

TABLE II

Typical Thermal Stress Factors For Various Materials

Material	Elastic Modulus in Tension, E (psi)	Coefficient of Thermal Expansion, α(in./in./°F)	Thermal Stress Factor, α x E (psi/°F)
Aluminum	10×10^6	13×10^{-6}	130
Stainless Steel	30×10^6	7×10^{-6}	210
Reinforced Plastics	$2\text{-}5 \times 10^6$	$3\text{-}12 \times 10^{-6}$	6-60

able with such structures are two of the most important requirements for rocket motor hardware, nose cones, nozzles, and thermal barriers.

Fig. 1 shows the strength-to-weight ratios of various construction materials, demonstrating the advantage of fibrous glass-reinforced plastics in providing higher-strength and/or lighter-weight rocket and missile structures.

Table I presents typical thermal-conductivity values for these materials, demonstrating the superior insulation of reinforced plastics as compared to metals. The tremendous potential of reinforced plastics under conditions of extreme surface temperatures for short durations, is immediately apparent.

An additional advantage of reinforced plastics for these applications is the favorable thermal stress factor, i.e., coefficient of thermal expansion multiplied by elastic modulus. For materials of low thermal conductivity, subjected to extreme surface temperatures, the thermal gradient across the material may be quite severe. It can be shown by analytical means that, for a given temperature gradient, shearing stresses will be imposed upon the insulating material in proportion to the product of elastic modulus and coefficient of expansion. Hence, for best results, a low thermal stress factor is desirable. Table II demonstrates that the thermal stress factors for reinforced plastics are significantly lower than those of metals, the values presented being applicable over a temperature range from room temperature to 500°F (Ref. 4).

Historical Background

Historically, experiments with plastic components for rockets date back many years. However, significant success has been achieved only since the development of suitable high-temperature-resistant thermosetting resins. More than six years ago successful rocket components were molded using chopped-glass fabric, chopped-glass roving, and batting with a binder of a high-temperature-resistant phenolic resin. Since then, many liquid and solid propellant rocket components have used this material, often with asbestos or Refrasil substituted for the glass reinforcement, for normal and moderately extended temperature-time applications.

The majority of the development work for rocket components has been performed using phenolic-resin binders. Epoxy and polyester resins have been used to some extent, and silicones to a lesser extent.

The suitability of such systems has been demonstrated on nearly all rocket systems of relatively short-duration firings; representative materials are available or under development from various manufacturers bearing trademarks such as AeroREZ, Astrolite, Fiberite, HT-5000, Pyrotex, Pyropreg, and Rocketon.

Time-Temperature Requirements

As can be expected for a given set of operating conditions and structure configuration, duration plays an extremely important role in the design of plastic rocket nozzles, thermal liners, and nose cones. Durations of less than 25 seconds have generally caused no serious problem; durations in excess of 25 seconds have often resulted in severe damage and subsequent component failures. This excessive damage may be attributed to the influence of the thermal energy of hot gases penetrating the film of molten reinforcement and pyrolized binder, thus heating the sub-surface layers to the decomposition temperature. Significantly improved results in long-duration firings, with high-combustion temperatures, have been observed when a cermet material or graphite was employed in the throat area or as an inert liner for the nozzle. However, the use of refractory materials results in an increased net weight for the nozzle assembly.

It is in the area relative to the time-temperature limitations of reinforced plastics, that personnel in the Structural Plastics Division of Aerojet-General Corporation have recently been engaged in research and development work.

It is believed that successful development of adequate ultra-high-temperature-resistant structures is dependent upon product formulation and fabrication techniques. Reinforcing agents, binders, and fillers are the primary formulation variables.

Theoretical Considerations

One may speculate, from a theoretical standpoint, regarding the properties desirable in a heat- and erosion-resistant plastic material.

Assuming a given environmental condition and heat flux, it is desirable for the structure to absorb as much heat as possible per unit of thickness and mass. In terms of thermodynamics, this may be stated:

$$\Delta H = (c_p)_v(T_f\text{-}T_\circ) + \Delta H_f + (c_p)_l(T_\circ\text{-}T_f) + \Delta H_v + (c_p)_g(T_{max}\text{-}T_\circ) + \Delta H_d$$

where ΔH is the change in heat content (or enthalpy) of the material from the state representing static (unfired) conditions (e.g., room temperature) to the state represented by the decomposed material

(gases); the other terms are defined:

$(c_p)_s$ = specific heat of material in solid state
$(c_p)_l$ = specific heat of material in liquid state
$(c_p)_g$ = specific heat of material in gaseous state
T_f = absolute temperature at fusion (i.e., melting)
T_s = absolute temperature at static conditions (e.g., room temperature)
T_v = absolute temperature at vaporization (i.e., boiling)
T_{max} = maximum absolute temperature reached by material in gaseous state
ΔH_f = heat of fusion
ΔH_v = heat of vaporization
ΔH_d = heat of decomposition

Not only should the material have a high ΔH value, but also it should satisfy the following conditions:

(1) Have a low thermal conductivity (k) and thermal diffusivity ($\frac{k}{c_p \rho}$ where ρ is the density).

(2) Be capable of resisting shearing stresses induced during flight (i.e., should not spall).

(3) Present a surface which is highly heat-radiating and aerodynamically smooth to hot gases.

Reinforcing Agents

Optimum strength properties are generally obtained from fibrous glass reinforcement; however, the softening point of glass is usually far below the operating temperature of the final structure. High-silica glasses (Refrasil) or asbestos are much more resistant to temperature, but lack high strength properties. Other physical properties to be considered include melting or liquidus temperature, heat of fusion, heat of vaporization, specific heat, emissivity, and thermal conductivity.

Regardless of which reinforcing media are used, it has been found that proper orientation of this material can produce marked effects on the rate of composite structure erosion. Work reported by various agencies has suggested this additional benefit from orientation; and recent work at Aerojet confirms this concept.

Reports from various companies working on heat-resistant plastics have shown that organic fibers which are thermally unstable at temperatures below 750°F, compared to glass, asbestos, and Refrasil reinforcements, have demonstrated superior thermal-erosion resistance at temperatures above 10,000°F in specialized tests (Ref. 5).

Fillers

Fillers play an important part in erosion-resistant insulation structures. Whether employed alone or in conjunction with a reinforcing agent (such as fibrous glass fabrics, rovings, or tapes), fillers can markedly increase relative erosion resistance of a part. The use of high-melting-point, low-thermal-conductivity fillers can increase service life of the compound surface by increasing temperatures during exposure. This in turn leads to a closer thermal equilibrium of the structure's surface with the environmental gases, thereby increasing heat radiation back into the hot gas zone.

Fillers which release volatiles, or sublime at elevated temperature into heat-absorbing substances such as water, carbon monoxide, carbon dioxide, etc. can produce a semi-transpiration cooling effect of the composite structure upon ablation. Such filler materials may release volatiles at temperatures from 150°F up to the temperature of combustion gases (5,000°F). However, such additives generally reduce the mechanical strength properties of the plastic and should be employed with due consideration to the specific operating requirements.

Figure 2. Tubular liner (Aeroez E601).

Binders

Binders used for the composite structure may include organic and inorganic materials, both alone and in combination. Various organic resins can be used which are highly resistant to heat and/or which will decompose leaving a heat-resistant carbon residue to hold the structure together. Upon decomposition in a high-temperature environment, high-heat-absorbing gases, such as hydrogen, oxygen, methane, and water vapor, are produced. Additional thermal protection is provided by the carbonaceous surface which becomes highly heat radiating when subjected to high temperatures. This factor is particularly important for protecting surfaces subject to aerodynamic heating.

The characteristics of phenolic and epoxy resins are very advantageous for rocket nozzles. Both have a fairly high specific heat, and high latent heats of fusion and vaporization; both can produce strong structures with fibrous reinforcements, particularly when molded under high pressures.

Most ultra-high-temperature plastic components have been fabricated using phenolic-resin binders. It is believed that this is due to the longtime familiarity in the plastics industry, which the epoxies do not yet enjoy.

With phenolics, high molding pressures and post-cures appear necessary for optimum performance.

TABLE III

Ignition Test Results

Material	Ignition Time (sec)	Burning Time (sec)	Fire Resistance Index (FRI)*	Figure of Merit**
AeroREZ E601	159	20	8.0	4.4
Fire retardant polyester plus antimony trioxide	78	13	6.0	3.3
High-temperature-resistant phenolic	168	43	3.9	2.2
Naval Shipyard Report; best sample	114	50	2.3	1.3
Epoxy resin plus chlorendic anhydride	87	49	1.8	1.0

* Fire Resistance Index (FRI)—Ratio of ignition time to burning time. The higher the index value the better the fire-resistant properties.

** Figure of Merit—The FRI value of each material relative to the epoxy-chlorendic anhydride laminate system.

Specimens were Type 181 glass fabric laminates, tested essentially in accordance with Specification L-P-406b, Method 2023.2.

TABLE IV

The Effect of an Oxy-Acetylene Flame and Gaseous Oxygen (GOX) on Various Erosion-Resistant Materials

Material	Exposed 45 sec to oxy-acetylene (in. erosion)	Exposed 45 sec to oxy-acetylene then 15 sec to GOX (in. erosion)
Graphite (Type ATL)	0.03	0.28
Copper	0.14	0.20
Steel (SAE 1020)	0.66	0.81
AeroREZ E702	0.20	0.20
High-temperature-resistant phenolic laminate	0.44	0.44
High-temperature-resistant silicone molding compound	0.47	0.47

TABLE V

Thermal Properties of AeroREZ E601, E602, and E702

Materials	E601	E602	E702
Specific heat, cal/gram	0.24	0.25	0.28
Linear coefficient of thermal expansion, /°F			
75°F—500°F	2.5×10^{-6}	6.5×10^{-6}	13.7×10^{-6}
Thermal conductivity, Btu/hr/sq ft/°F/in.			
Mean temp.— 60°F	1.26	1.45	1.73
Mean temp.—160°F	1.42	3.18	1.93
Mean temp.—250°F	1.54	4.07	2.87

These factors, and the volatiles released by the condensation reaction of phenolics, complicate the fabrication of structures using these resins; there is frequent difficulty in making large, thick sections without voids or blisters.

Epoxy resins, on the other hand, can be molded at low pressures and release no volatiles during cure. Moderately filled, liquid-grade epoxy resins can be cast. Until recently, epoxy resin formulations suitable for elevated-temperature service were unobtainable. Aerojet-General has developed high-temperature-resistant epoxy formulations designed for improved flame resistance and is currently working on development of materials with greater resistance to hot-gas erosion for use in rocket motors.

Recent Developments

Experimental flame- and heat-resistance epoxy resin-base molding and laminating formulations (AeroREZ E601 and E701) have been developed at Aerojet which are capable of providing excellent thermal insulation for metal structures. Fig. 2 shows a tubular liner fabricated of AeroREZ E601, which was designed to protect a rocket motor nozzle adapter during operation of a safety device. This part was required to withstand exposure to temperatures in excess of 3,000°F. Comparative ignition test data for various flame-resistant plastics are presented in Table III, demonstrating the overall superiority of AeroREZ E601 laminate.

Another recently developed experimental plastic material, AeroREZ E602, was used in the solid-propellant grain support structure shown in Fig. 3. The plastic laminate served to insulate the metal core structure from the hot erosive combustion gases of a solid-propellant rocket motor. This material consists of a thermosetting resin-ceramic system with a fibrous glass reinforcement. This material, along with AeroREZ E702, an experimental pre-mix molding composition with the same base formulation, was developed as the result of extensive oxy-acetylene torch tests. Fig. 4 shows a typical test of this type; and Table IV presents typical oxy-acetylene torch test results for some of the more promising materials investigated. It was noted that AeroREZ E702 eroded at approximately one-half the rate of conventional high-temperature reinforced phenolic resins when exposed to the hot gases of the oxy-acetylene torch (approximately 5,000°F).

These materials are currently contributing to the success of various rocket motors by protecting various metal components from hot gases. The use of

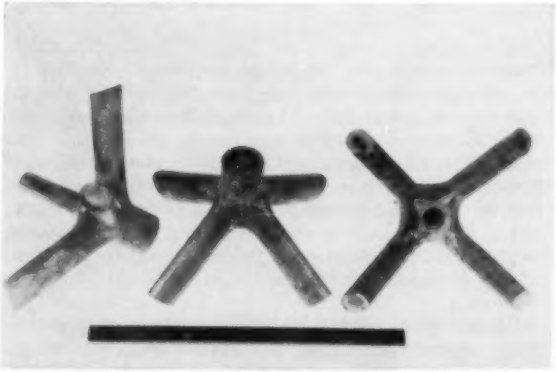

Figure 3. Solid propellant grain support (Aeroez E602).

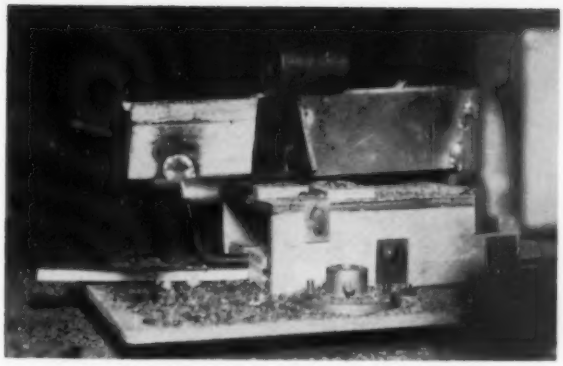

Figure 4. Oxy-acetylene torch test apparatus.

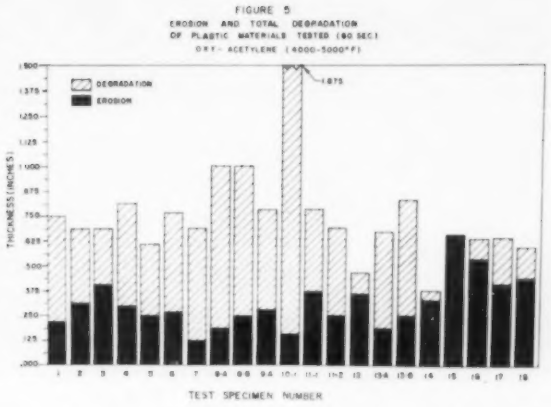

Figure 5. Erosion and total degradation of plastic materials tested (60 sec.) oxy-acetylene (4,000-5,000°F).

lightweight plastic thermal insulation for metal structures permits a considerable weight saving by reducing the thickness of metal otherwise required. Thermal properties of these AeroREZ materials are presented in Table V.

TEST METHODS

1. The Oxy-Acetylene Torch Test

It was desired to employ a rapid and inexpensive test method for screening and evaluating materials for rocket and missile applications. An oxy-acetylene torch test was employed as a convenient means for providing temperatures of approximately 5,000°F and gas velocities estimated to approach Mach 0.5. This is considered to approximate the temperature-gas velocity conditions encountered within rocket-motor combustion chambers and convergent sections of nozzles.

The test apparatus is shown in Fig. 4. This photograph was taken using a blue filter to mask the flame and show, more clearly, the portion of the sample being tested. To obtain the greatest possible erosion under these conditions, the maximum amount of gas that would burn smoothly was supplied to the torch, using the largest tip available. A neutral flame was used in all tests. Wedge-shaped samples were used as test specimens, after it was found that flat specimens (held vertically to the flame in order to obtain maximum erosion) tended to produce unstable combustion and extinguish the torch. The specimens were held rigidly in place with the leading edge touching the blue cone of the flame, as shown in Fig. 4, because at a distance of ½" from the flame, the temperature of the test specimen was reduced by about 2,000°F.

Approximately one hundred tests were conducted in this fashion, wherein various formulations of epoxies were compared with high-temperature-resistant phenolic, melamine, and silicone laminates and moldings.

In an initial test series, duplicate test specimens were tested at two different angles. One specimen was tested at an angle of 0° to the torch axis, the other at 25° to the torch axis. The test results indicated that the erosion characteristics are independent of contact angle over this range. Methods of analyzing these tests were carefully considered. Temperature measurements at various locations and weight loss measurements were not considered satisfactory for evaluation purposes.

It was found that measurements of "erosion" and "degradation" were the most meaningful. The "erosion" value was determined by the depth of the specimen which eroded away during actual exposure to the flame. "Degradation" was obtained by physically digging into the burned and charred portion of the specimen until a sound, strong, portion of the specimen was reached. "Erosion" and "degradation" of various plastics subjected to the oxy-acetylene torch test are shown in Fig. 5. (*Note:* Results are presented here to indicate the range of values and the nature of the data obtained, rather than for the purpose of rating specific materials.) Test specimen No. 7, a modified epoxy with refractory filler, demonstrates the least "erosion" and a moderate amount of "degradation". This material is therefore recommended for moderate-to-low-velocity (below Mach 0.5) hot-gas-flow applications, as in forward insulation liners of rocket motors. Test specimen No. 14, using Refrasil reinforcement, shows the least amount of "erosion"-plus-"degradation" and is better suited for higher-velocity hot-gas-flow applications, as in nose cones and rocket nozzles.

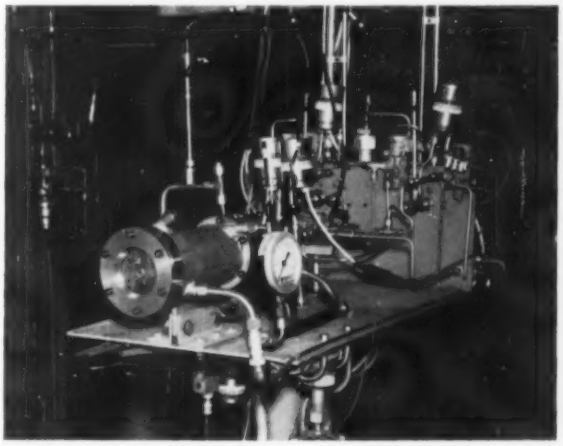

Figure 6. Gaseous oxygen-hydrogen rocket test motor.

2. The Hydrogen-Oxygen Rocket Motor Test

A specially designed gaseous hydrogen-oxygen rocket motor was constructed for evaluating various materials for use in rocket nozzles and blast tubes.

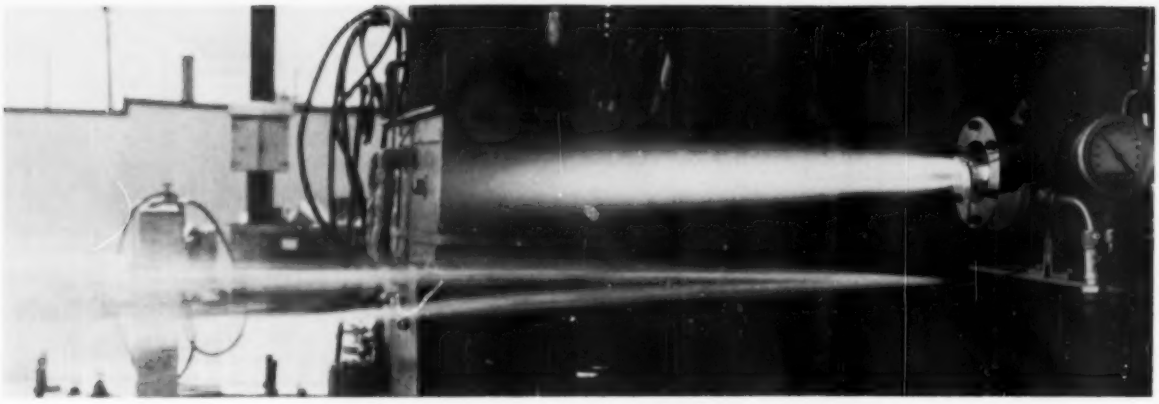

Figure 7. Gaseous oxygen-hydrogen rocket test motor.

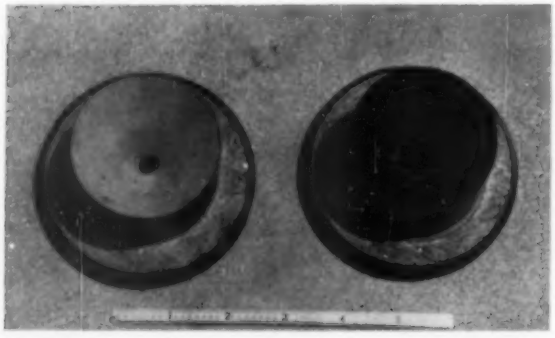

Figure 8. Typical test specimen before and after firing.

The test assembly is shown in Fig. 6. Fig. 7 shows the unit in operation. Materials are tested as small nozzles fitting directly into the motor. A typical test specimen before and after firing is shown in Fig. 8. The unit operates with a chamber pressure which can be adjusted between 200 and 1,000 psig, and a stagnation gas temperature which can be controlled from 3,000°F up to 6,000°F.

With this motor it is possible to reproduce almost the identical conditions that may exist in any rocket motor nozzle, with the exception of the exact chemical composition and specific heat ratio of the combustion gases. Inlet and exit nozzle angles, temperature, gas flow, chamber pressure, duration, and most variables associated with appropriate nozzle design may be evaluated rapidly and at a very low testing cost.

In order to simulate typical rocket firings, plastic nozzles were tested under the following conditions:

Initial chamber pressure	525 psi
Stagnation temperature	5,400°F
Mass flow rate	2 lb/sec/in.^{2}
Mixture ratio	4.5:1
Characteristic exhaust velocity	8,300 ft/sec

The test motor was equipped with a pressure switch which automatically shut down the motor when the chamber pressure was reduced to 300 psi as a result of nozzle erosion. A post-fire purge of nitrogen was then automatically initiated to prevent continued burning or oxidation of the test nozzle after completion of the test.

Test nozzles were fabricated from various high-temperature materials employing the information derived from the previous oxy-acetylene torch tests.

a. Effect of Reinforcements

Nozzles were made specifically to determine the effect of fiber orientation on plastic nozzle erosion resistance. Specimens were fabricated by high-pressure molding using (1) bulk Refrasil fibers, (2) woven Refrasil cloth laminated, and (3) woven Refrasil cloth, chopped ½" x ½" squares and ¼" x ¼" squares, with a high-temperature phenolic resin. The woven fabric laminate specimens molded under high pressure with the cloth direction perpendicular to the gas flow, produced about twice the erosion resistance compared to specimens made of the compression-molded chopped cloth or bulk fibers. Fiber orientation and length, fabric configuration, resin ratio, and density all appear to be factors that significantly affect the erosion rate and are at present being studied more closely in the Aerojet hydrogen-oxygen rocket tests.

b. Effect of Fillers

A decrease in erosion resistance was observed when refractory fillers were added to specific formulations of reinforcement and binder for test in the rocket motor. This lower erosion resistance is believed to be a function of lower mechanical strengths than the type of fillers used. Oxy-acetylene test had indicated superior results with this type of construction. In view of these results, it is believed that refractory fillers may offer considerable erosion resistance if mechanical strength can be improved. This was evident from examination of the entry and exit sections of the nozzles tested, which showed very slight erosion in these areas; whereas in the throat section, where higher mechanical stresses are produced, the material appeared not to have eroded, per se, but rather to have blown out in pieces as a result of low mechanical properties.

c. Protective Coatings

Various protective coatings, flame sprayed on compression-molded Refrasil-phenolic nozzles, were investigated in an effort to improve the erosion resistance of the plastic. Coatings were tested with thicknesses ranging from 0.010" to 0.030" using: (1) Al_2O_3, (2) $CrNiB_n$, (3) $ZrO + Al_2O_3$, and (4) molybdenum. These coatings tended to decrease rather than improve nozzle life. The increased rate of failure is believed to be a result of the inability of the decomposition products of the plastic to diffuse rapidly through the micropores of the flame sprayed coating, thereby causing high localized stresses. Fail-

ure probably initiates at the throat, where the shearing forces are greatest; and an increased erosion rate results because of the turbulence and impact of coating particles impinging upon the surface during expulsion through the nozzle. However significant improvement was obtained with protective coatings, graphite inserts, etc. when changes were made in the test nozzle design so as to provide for removal of decomposition products of the plastic from the nozzle during test firing.

The results of some typical test firings are shown in Fig. 9. These specimens have been sectioned at their approximate centers to permit observation of the exposed and adjacent areas. Fig. 10 shows a magnified view of a sectioned compression-molded sample after test firing.

Since the installation of this test rocket, a considerable number of commercially available high-temperature materials and Aerojet-developed materials have been evaluated. From these tests it has been established that the erosion resistance of thermal-insulating materials tested under these conditions, can be improved by (1) using higher melting reinforcements, organic fibers such as nylon being less desirable than inorganic fibers; (2) controlling the orientation of fiber reinforcements; (3) judiciously selecting the type and amount of filler material used; and (4) controlling and directing the removal of gases caused by the decomposition of the plastic.

Conclusion

Considerable knowledge has been gained in the areas of practical application of existing high-temperature plastic materials, mainly in an effort to save weight. However, plastic materials for use as heat- and erosion-resistant structures in advanced rocket motors must be developed with considerable design consideration given to the areas of applicability. For example, materials which are outstanding on exposure to high-temperature, low-velocity (below Mach 0.5) gases are necessarily not optimum for higher gas velocities, and vice versa.

Within the rocket motor, heat transfer rates and resulting wall temperatures vary considerably, being maximum at the nozzle throat. Operating parameters such as stagnation temperature, chamber pressure, exhaust velocity, etc.; the specific combustion products (primarily gaseous, but which may also include solid particles); and structure design such as nozzle throat diameter, expansion ratio, etc. can markedly affect the performance of insulation materials. Accordingly, these factors need to be considered in establishing a design for the insulation liner, nozzle, thrust control, etc.

Acknowledgments

The authors appreciate the assistance given to them by various personnel at the Aerojet-General Corporation, particularly the suggestions of Mr. E. L. Rucks, Manager of the Structural Plastics Division; A. M. Cecka of the Engineering Department; J. Goldberg, Head of the Materials Application and Process Development Group; H. A. King, Head of the Research Group; and B. L. McFarland of the Systems Division.

Much of the data included in this paper was obtained through the efforts of M. Varlas, D. L. Robbins, R. E. Medick, J. F. Creedon, B. G. White, F. S. Spanninger, and other members of the Structural Plastics Division, and of L. L. Linn of the Aerojet Proving Grounds Testing Facility.

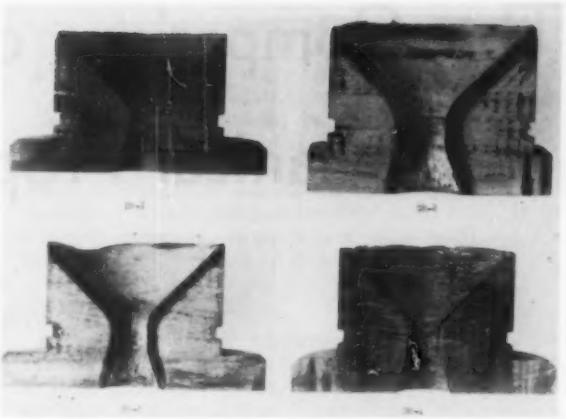

Figure 9. Fired test nozzles sectioned vertically through approx. throat diameter.

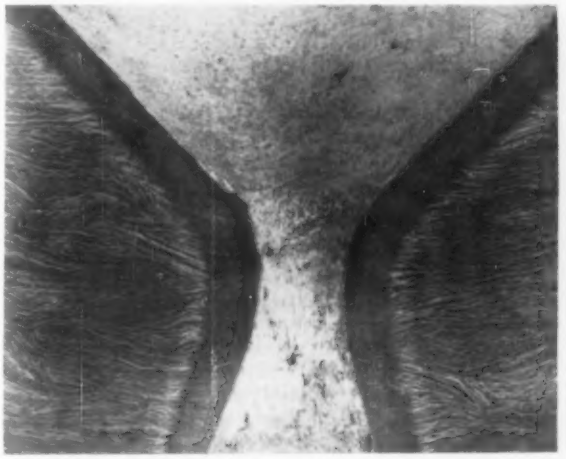

Figure 10. Fired test nozzles sectioned vertically through approx. throat diameter (magnified two and one half times).

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The Comparison of Time Dependent Mechanical Properties of Plastics

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WHEN A MECHANICAL STRESS is applied to material which exhibits time dependent mechanical properties, the strain or deformation that takes place is a function of the rate at which the stress is applied and the length of time the stress is allowed to act. In many applications plastics are required to support mechanical loads that may be applied either rapidly or slowly and for long times or for relatively short times. It is, therefore, necessary to have a clear understanding of the time dependency of mechanical properties of plastics in order to achieve proper engineering design with these materials.

Because the engineer is trained in the subjects of mechanical design and strength of materials based on the more traditional engineering materials such as steel and concrete, he makes the assumption that mechanical properties are independent of time. This assumption is approximately correct for these older engineering materials at room temperature but is not valid for many plastics and as a matter of fact is the cause of many problems of design with the traditional engineering materials when the application involves elevated temperatures.

Under the application of a mechanical *stress*, time dependent materials will deform to some extent instantaneously and then will continue to deform at a varying rate either until a fixed degree of strain is reached or until failure occurs. This type of behavior is called creep. Under the application of a mechanical *strain* of some fixed magnitude, time dependent materials will exhibit a stress resisting this strain that decreases with time. This type of behavior is called stress relaxation.

Both of these types of behavior involve the time dependent characteristics of the materials under consideration, and these characteristics are, of course, dependent on the temperature at which the application of the material is to be made. In addition, all other mechanical properties such as hardness and impact resistance must also be time dependent since they involve mechanical loadings of either a creep or stress relaxation nature or a combination of these two.

It is apparent that some method of determining the time dependent characteristics of plastics is needed that will permit a comparison of one material with another in this respect and give insight into the effect of temperature on the time dependency. In this paper we will discuss the utility of a dynamic test in rapidly evaluating the time dependent characteristics. Such a test permits the controlled variation of the time of loading and test temperature over a wide range and hence gives a characterization of materials.

BASIC PRINCIPLES

Creep

If a plastic material is subjected to the continuous application of a constant load, for example as an electrical insulating mounting for a chassis, the following creep characteristics may be expected. Referring to Fig. 1, upon the application of the chassis' weight to the mounting a constant stress, S, will be applied to the plastic material. At the instant this stress is applied an instantaneous strain, ϵ, of some magnitude, A-B, will take place in the mounting. If the load is immediately removed the strain in the plastic will completely disappear. In other words, the material will behave in an ideal elastic manner if the load is applied and removed in essentially zero time.

If instead, the load is maintained on the mounting for some time, t, then the strain will increase in some manner described by the curve B-C-D-E. In the region B-C the strain rate is secondary creep. If the plastic mounting is over-loaded, at some time, D, the rate of straining will increase until failure takes place at E. This region is called tertiary creep and indicates structural changes and/or dimensional changes are taking place.

The location on the strain and time scales of the points B,C,D,E is dependent on the material being studied, the temperature of application and the stress level. It is apparent that proper design should limit the strain magnitude exhibited during the useful lifetime of the mounting to some reasonable value so that, in this case the chassis, will be properly supported.

The shape of the creep curve is dependent on the relaxation times of the cohesive forces in the material. If these relaxation times could be computed from consideration of the structure of the polymer used, then the task of describing the time dependent properties would be greatly simplified since the creep curve could be predicted from the relaxation times. No satisfactory way of doing this has as yet been found, but in principle a distribution of relaxation

times may be determined from the creep curve, and this could be used to describe the time dependent properties of the material (Ref. 1).

The effects of time under load on the strain recovery characteristics are shown by the dashed lines C-F-G and D-H-I. If the load is removed at point C, an instantaneous recovery will take place, C-F, followed by a delayed recovery, F-G. The time dependent recovery of strain will reach some limiting value, G, and this strain will be permanently exhibited by the material unless a stress is applied opposite in direction to the original loading. If the load is removed at point D the same recovery pattern will be exhibited except that the permanent strain or deformation, I, will be greater.

Stress Relaxation

If a polymer mass is subjected to a constant strain, the stress in the polymer will decay as a function of time. An example of this type of mechanical loading would be a plastic gasket clamped between two metal flanges. When the flanges are clamped together a fixed compressive strain is applied to the gasket. The plastic material will exert a stress, S, resulting from this strain, E, that may decay with time in the manner shown by curve A in Fig. 2.

At time zero the strain is applied which is resisted by the stress, So, in the material. As time progresses the stress will reduce as the cohesive forces in the material relax. From this curve we may define the relaxation time for the material. It is the time required for the stress under constant strain to decrease to a value of 1/e of its original value (e = the natural logarithm base).

For some plastic materials, after a sufficiently long enough time under constant strain, an equilibrium stress (Z) will be reached that remains essentially the same for any continued period of time. Materials which exhibit this behavior usually have a network structure in which the further relaxation of cohesive forces is prevented by a cross-linked structure or permanent crystalline structure. If no network structure is present the stress may eventually decay to zero as shown in curve B.

If at some time t_x the applied constant strain is removed from the material, some recovery would be found in material A. The strain recovery would not be complete and would take some period of time to reach a constant value. When the applied strain is removed from material B, there would be no strain recovery.

The behavior of plastic material in stress relaxation applications should be compared to that assumed for the traditional elastic structural materials, such as steel. This idealized behavior is shown in curve C. Upon the application of strain, a stress is developed which remains constant with time. If the strain is removed, there would be a complete and instantaneous recovery of strain.

Dynamic Properties

From the above it becomes apparent that proper evaluation of polymeric materials requires a study of time dependent properties. Any point on each of the curves shown in Figs. 1 and 2 may be considered representative of a time dependent modulus for the material. This means that, if we are interested in the load deformation characteristics of a material over some specific useful lifetime we can determine a design modulus from the creep or relaxation curves.

The time dependent characteristics of materials may also be determined by a dynamic measurement. If a stress or strain which oscillates in a sinusoidal manner is applied to a plastic specimen, the response of the material will be dependent on the frequency of the oscillation. By any one of several methods (Ref. 2) it is possible to apply such a loading and determine the modulus of elasticity in-phase with the loading, E_1, and the loss modulus or stiffness to recovery from deformation, E_2. The complex time dependent modulus, E^*, is given by:

$$E^* = E_1 + jE_2$$

The ratio of E_2 to E_1 is an indication of the energy lost as heat and is called the loss factor.

By studying the variation of the two moduli as a function of both frequency and temperature, a complete picture of the mechanical characteristics of materials can be quickly and easily determined. Since the response of the material under study will be dependent on the relaxation times of the cohesive forces in the material, it should be possible in principle to determine either the creep or stress relaxation characteristics from the dynamic data (Ref. 1). The actual manipulations involved are rather difficult and time consuming, but because of the ease with which dynamic data can be obtained, especially

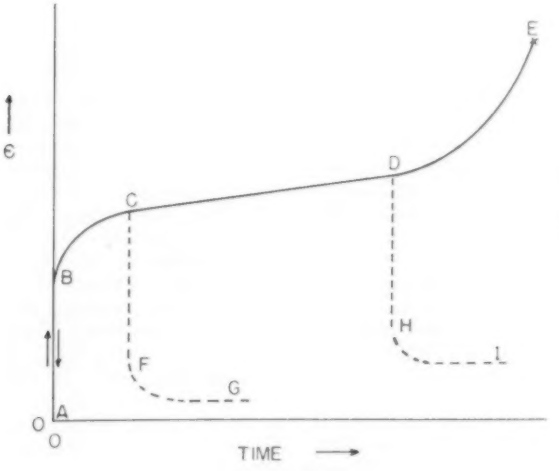
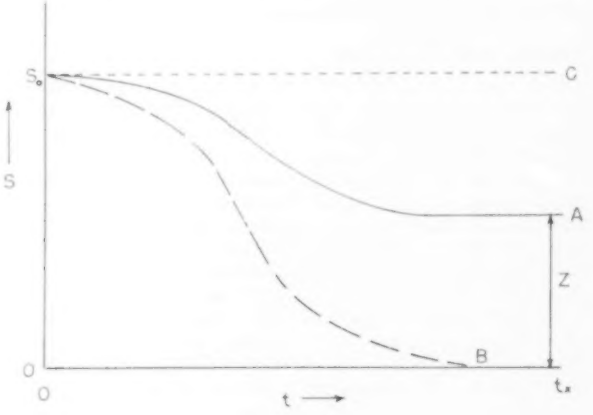


Figure 1.



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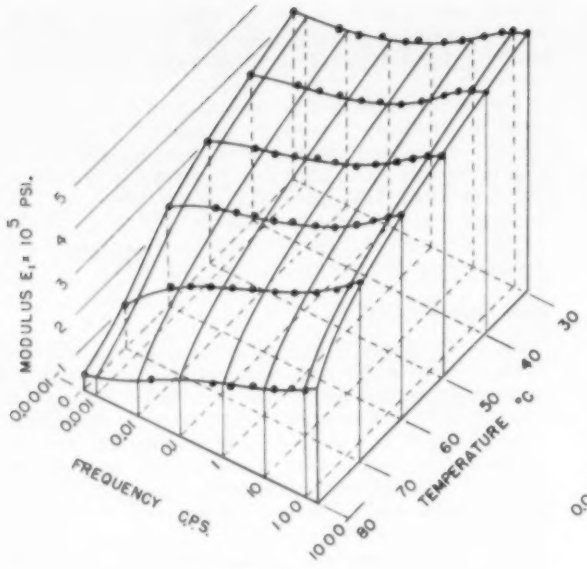

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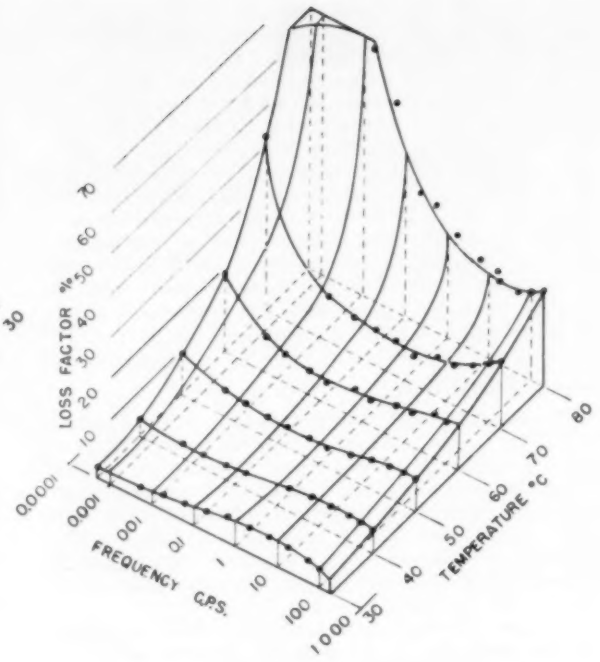

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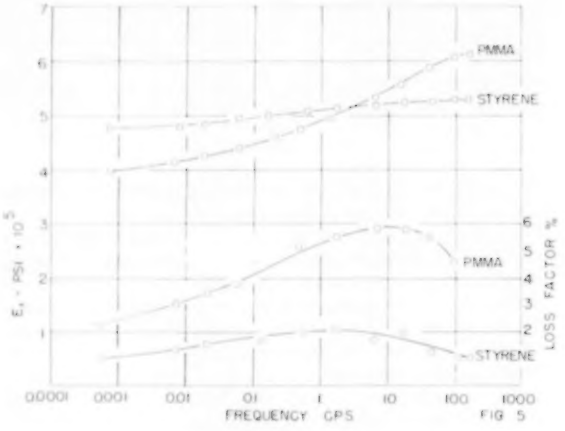

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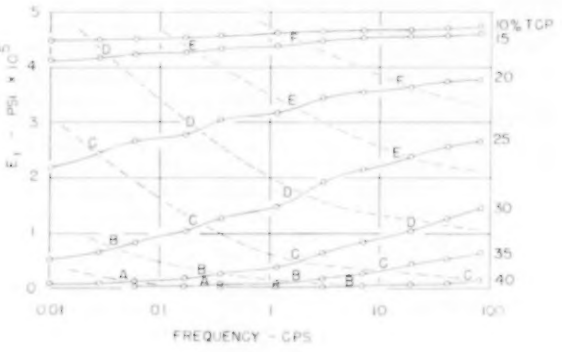


Figure 6.

for materials with very short relaxation times, this method is becoming more popular.

Results and Discussion

The results of dynamic tests on polymethyl methacrylate are shown in Figs. 3 and 4. This data was taken on a mechanical spectrometer previously described (Ref. 3). At any given temperature, for example 30°C, the in-phase modulus, E_1, increases as the frequency is increased. Since an increase in frequency is comparable to a decrease in the time under load, we may say that if the modulus changes with frequency then in a constant load application of the material creep or stress relaxation will be taking place. Similarly if the modulus changes with temperature at a constant frequency we may expect changes in the creep rate or stress relaxation with temperature, the greater the change in the dynamic properties, the greater the changes in the static load behavior.

Polymethyl methacrylate shows a region of marked change in the in-phase modulus above 60°C, particularly in the low frequency range. This indicates that caution should be exercised when applying this material under these conditions. The regions on the frequency-temperature plot where the in-phase modulus is changing most rapidly can be most easily located by inspection of the loss factor data. The greatest change in modulus will coincide with regions of high loss factor. This is borne out in Fig. 4. At room temperature there is a small maximum in the loss factor corresponding to the greatest frequency dependence of the in-phase modulus. Similarly the large change in modulus above 60°C is shown by the rapidly increasing loss factor in this region.

In order to compare two materials at some given use condition, say 30°C, it is only necessary to obtain their dynamic response characteristics. Fig. 5 shows the in-phase modulus and loss factor of polystyrene

and polymethyl methacrylate for comparison. These two materials are rigid, glassy state, plastics with high modulus. Polymethyl methacrylate exhibits a greater time dependence as shown by the greater slope in the E_1 vs. frequency curve and the higher value of loss factor. It should be pointed out here that a higher value of loss factor indicates a greater ability to absorb energy. Hence, if a small sacrifice in time dependency of modulus can be tolerated a gain can be achieved in shock resistance and damping capacity.

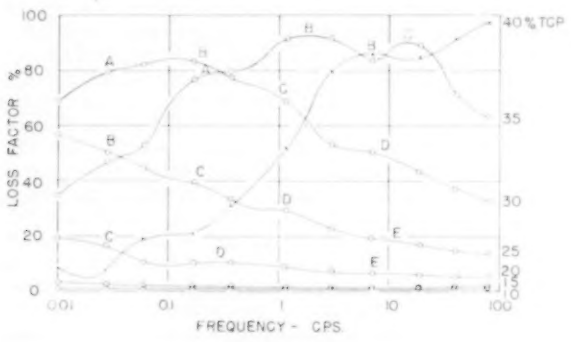
The change in mechanical properties due to structural or composition variations can be easily evaluated for engineering purposes by the dynamic test. For example, external plasticizers are added to plastics in order to decrease their in-phase modulus, or stiffness, and to increase their energy absorption characteristics. Figs. 6 and 7 show the dynamic properties of polyvinyl chloride as they are affected by the addition of tricresyl phosphate (TCP) as a plasticizer. At any given frequency the in-phase modulus decreases rapidly above 15% TCP. It should be noted that at each level of plasticizer content the modulus is quite frequency- or time-dependent. This indicates that in this time scale range rapid creep or relaxation can be expected. The loss factor reaches a maximum of almost 100% at 35% TCP. The various small peaks on the loss factor curves are labeled by letters and correspond to inflection in the frequency dependent modulus. They shift to higher frequency as the plasticizer content is increased, indicating that the response of this material is of a viscoelastic nature and that the addition of plasticizer to obtain a low modulus does not bring about a true rubberlike elasticity.

Another structural variation of considerable interest today is the degree of branching in polyethylene. The polymerization conditions may be varied so that a fairly well controlled degree of branching is present. Using the number of methyl groups per 100 carbons in the polymer chain as an indication of branching, the time dependence of the mechanical properties on branching is shown in Fig. 8. The following methyl groups per 100 carbons are shown:

Curve A	0.14	CH_3/100 C atoms
Curve B	0.85	CH_3/100 C atoms
Curve C	1.80	CH_3/100 C atoms
Curve D	2.10	CH_3/100 C atoms

It is readily apparent that the lower the methyl group content, and hence, the degree of branching, the higher the modulus at high frequency or short time scale of loading. It is also apparent that the lower the methly group content the greater the time dependency of the modulus as indicated by the slope of the curves. In other words, we must expect more creep or stress relaxation in the more linear material.

An examination of the standard mechanical properties of linear polyethylene and isotactic polypropylene does not show any very marked differences between the two materials. But an examination of the time and temperature dependency of these two



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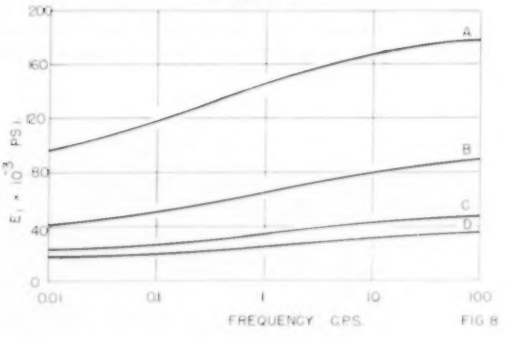

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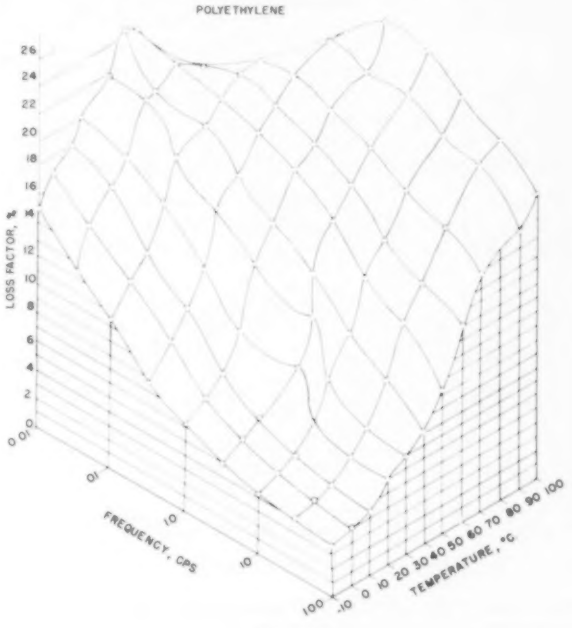

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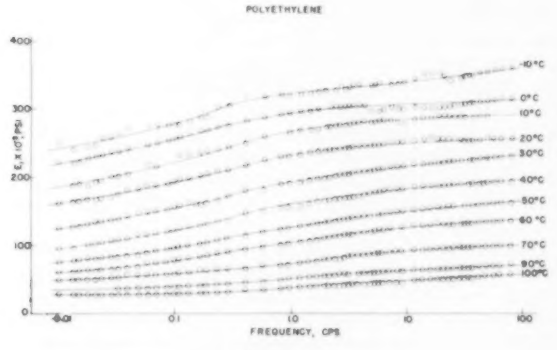

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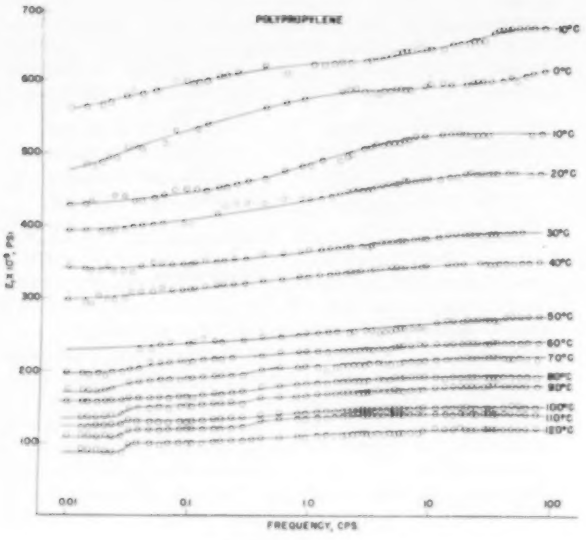

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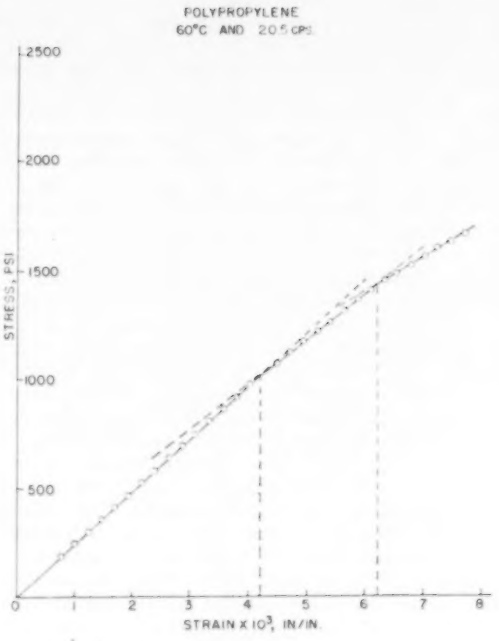

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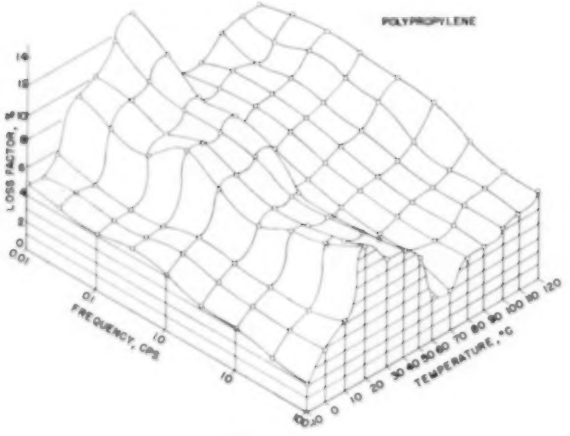

Figure 12.

materials indicates that their mechanical responses are distinctly different. Figs. 9 and 10 show the frequency and temperature dependence of the modulus of linear polyethylene and isotactic polypropylene. The response of polyethylene is both frequency and temperature dependent as indicated by the slope of the modulus curves and their vertical shift with temperature. On the other hand, polypropylene does not exhibit as much time dependence (especially at room temperature and above). This is shown by the flatness of the frequency response. There is a marked change of modulus with temperature, indicating that structure changes with temperature but even at elevated temperatures the response does not seem to be viscoelastic.

These observations are confirmed by the loss factor plots of Figs. 11 and 12. Polyethylene exhibits a high broad maximum which shifts to higher frequency with higher temperature. This indicates high energy-absorbing characteristics but great time-dependency. Polypropylene, on the other hand, exhibits at least two peaks but they are of low magnitude and are essentially frequency independent. The lowness of the loss factor indicates a rapid snap-back or recovery from deformation, a property that would not be readily apparent from standard engineering tests.

One more point should be made with regard to permanence properties. For those cases where extremely good engineering design is of the utmost importance, such as military applications, consideration should be given to the effect of mechanical deformation itself on the properties measured for the material. By obtaining the dynamic properties of plastics under conditions of controlled strain magnitude, the strain limit of confidence in the data obtained can be determined. This is called the limit of linear viscoelastic response. Fig. 13 depicts the variation of in-phase modulus with strain magnitude for polyethylene at 40°C and 20 cps. It should be noted that a straight line relationship exists between stress and strain up to about 3×10^{-3} in./in. strain. In other words, up to this strain the modulus is constant. Above this strain magnitude the deformation causes a change in structure and the properties exhibited above this strain level will exhibit additional impermanence. Hence, the limit of linear response should be a very important design criterion for the engineer.

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1. See T. Alfrey, "Mechanical Behavior of High Polymers." Interscience Publishers, Inc., New York, 1948.

2. See F. R. Eirich, "Rheology Theory and Applications," Chapter 11, J. D. Ferry, Academic Press, Inc., New York, 1958.

3. B. Maxwell, *ASTM Bulletin* No. 215, July 1956.

INTERFACIAL POLYCONDENSATION
A Versatile Method Of Polymer Preparation

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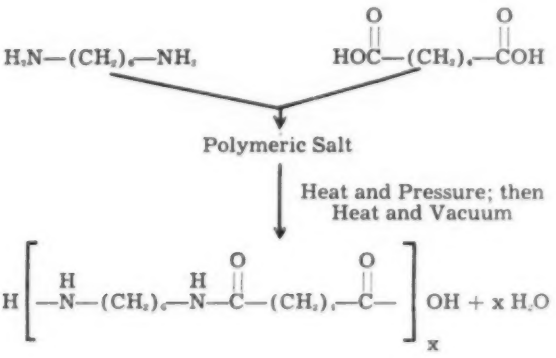
CONDENSATION POLYMERIZATIONS for many years have been based upon slow, reversible organic reactions which require elevated temperature, and in many cases reduced pressure, for the removal of volatile by-products. These methods were studied extensively in the classic work of Carothers and his co-workers (Refs. 6, 38) on polyamides. His research established and clarified many of the fundamental requirements for the preparation of condensation polymers.

(Eq. 1)



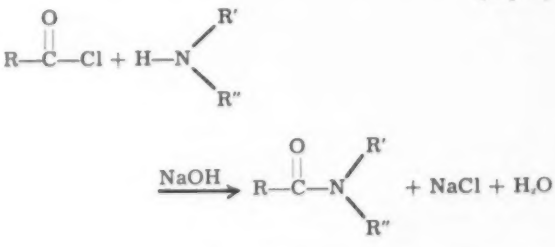
6-6 Polyamide

Eq. 1 illustrates the condensation of difunctional intermediates to form a linear polyamide. Since the polymer forms as a molten or plastic mass, the process is generally known as melt-polycondensation. Many polyamides and polyesters have been made in this way, but the method has been limited to intermediates and polymers which were thermally stable at temperatures between 200° and 275°C. In order to get around the requirement that the polymer be molten, high boiling solvents or plasticizers have been used (Ref. 38) and some polymerizations have even been carried out in the solid state (Ref. 21) or as a suspension in a nonsolvent heated below the melting point of the polymer (Ref. 45).

Since the melt polymerization process is also time consuming and a difficult laboratory technique, there has been a need for general, rapid polycondensation methods which could be run in simple equipment under atmospheric conditions. This goal has been achieved and such a method has been described recently in the patents and papers from several laboratories in this country and abroad.

This low-temperature method employs the chemistry of an old familiar reaction, the Schotten-Baumann reaction (Ref. 48), in which an organic acid halide is combined with a compound containing an active hydrogen atom as in the functional groups, —OH, —NH, and —SH. (Gerhardt reacted benzoyl chloride with aniline over 100 years ago [Ref. 18], but did not use aqueous alkali as an acid acceptor.)

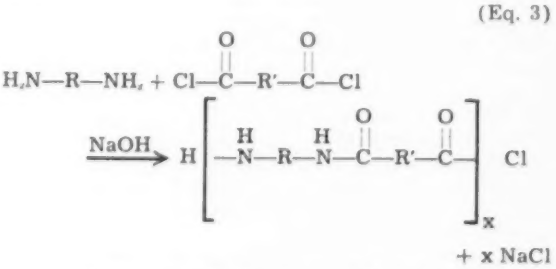
(Eq. 2)



(R—, R'—, and R"— are organic structures)

By making the two complementary reactants bifunctional or even by placing both functions in the same molecule one can now form high polymers (Eq. 3).

(Eq. 3)



(where x is in the range of 25 to 100)

It is customary to carry out the polycondensation between the fast-reacting intermediates in two immiscible liquid phases, one of which is preferably

water. The water phase contains the diamine or diol and any added alkali. The other phase consists of the diacid halide and an organic liquid, such as carbon tetrachloride, dichloromethane, xylene, or hexane. The polymerization takes place at or near the liquid interface and therefore the process has been named *interfacial polycondensation*.

Interfacial polycondensation has been used to prepare polyamides, polyurethanes, polyureas, polyesters, polythiolesters and polysulfonamides. Although the conventional condensation polymerization employs reactants from which a by-product is eliminated, addition reactions which lead to condensation polymers may be carried out by interfacial polycondensation. Illustrative reactions are those of diisocyanates with diamines to yield polyureas (Ref. 33) and *bis* epoxides with diamines to produce polyamines.

In Table I a group of recipes for the preparation of various polymers has been collected. These should serve as demonstration preparations and as a starting point for experimentation with new intermediates. In the two following sections are general experimental directions for laboratory preparations and a description of the unstirred procedure for polyamides. Following that is a general discussion of the mechanism of the process and the variables affecting it and then a summary of the literature and interesting highlights on the several structural classes of polymers. No attempt has been made to collect or refer to all of the literature on the use of two-phase polymerization methods.

Stirred Interfacial Polycondensation Procedures

While stirring is not essential for all interfacial polymerizations, it is usually desirable in order to obtain high yields of powdered or granular products which are easily isolated, washed and dried. The two phases are combined rapidly with vigorous agitation. A convenient apparatus is a home blender. Since the diacid chloride is the more unstable of the two starting materials, it is generally advisable to add the solution of it in the organic solvent to the stirred aqueous solution. A polymerization started at room temperature may warm up to 50°—60°C from the heat of the reaction and heat from stirring action. With diacid chlorides that are particularly sensitive to hydrolysis, the product is improved if the solutions are cooled to 5°—10°C. Most polymerizations are complete in 2 to 10 minutes. The high polymer will probably have precipitated and may be separated by filtration of the mixture. Polymers that are soluble in the organic solvent may be isolated by evaporation of the solvent or by addition of a precipitant with agitation. Emulsions may be broken by evaporation of the solvent, the addition of a water-miscible organic liquid, such as acetone, or by the addition of a salt.

In the isolation step sintered glass funnels are preferred because they minimize contamination of the polymer. The polymer should be washed free of salts, detergents and any unreacted intermediates. The washing step may be hastened by the use of aqueous alcohol or acetone.

The yields from stirred interfacial polycondensations are commonly between 75% and 100%. The section on mechanism will make it clear why polymer may be obtained at low over-all yield.

Interfacial polycondensation is affected by numerous variables which are discussed elsewhere. In addition, several variations in procedure have been developed which may be required or may be considered alternate systems. If the reactant which is normally dissolved in the aqueous phase has little or no solubility in water, it may be dispersed or dissolved in a portion of the organic solvent and added to the aqueous phase. Such a step may also be used with a water-soluble intermediate and this may assist the final admixing of the acid chloride solution. Improved yields have been reported for certain polyurethanes (Ref. 24b) if a portion of water-miscible solvent is added to the usual water-organic solvent system. The addition of salts to the aqueous phase will reduce the hydrolysis of acid halides by reducing the solubility of these intermediates in the water (Ref. 70). Jones and McFarlane (Refs. 24a, 28) describe another method for reducing interfering hydrolysis in the preparation of polyurethanes. The diamine is first formed into a neutral salt solution in water, this is mixed with the bischloroformate solution in a water-immiscible solvent, and then alkali is added to the system to liberate the diamine and permit polymerization. The hydrolysis of a chloroformate is relatively slow in water but increases rapidly with hydroxyl ion concentration.

Although nearly all of the literature describes only batch procedures, interfacial polycondensation is obviously easily converted to a continuous flow process. An apparatus for accomplishing this has been patented (Refs. 23, 59) and other devices are reported by Beaman, et al (Refs. 1, 36, 55). One of these is illustrated in Fig. 1.

Unstirred Interfacial Polycondensation Procedure

If the complementary phases for an interfacial polycondensation are brought together *without stirring* and if the organic liquid is a nonsolvent for the polymer, a thin film of polymer will be formed at once at the interface. Under the right conditions, this polymer gel* is tough and has high molecular weight. When the film is grasped and pulled from the area of the interface, more polymer forms at once and a collapsed sheet or tube of polymer may be withdrawn continuously (Refs. 31, 37, 41) (Fig. 2). This type of polymerization has been used as a lecture demonstration (Ref. 40). Since the omission of stirring decreases the number of variables, the method has also been used to study the polymerization mechanism.

The formation of a continuously removable film of polymer is most readily carried out with aliphatic polyamides. A system, described in more detail in Refs. 40 and 41, is as follows: A solution of 1.5 ml. sebacoyl chloride in 50 ml. tetrachloroethylene (perchloroethylene) is placed in a clean drinking glass or beaker. Upon this is carefully poured a solution of 4.0 g. sodium carbonate and 2.2 g. hexamethylenediamine in 50 ml. water. The edges of the glass at the interface are freed of strings of polymer and then the film is grasped at the center and pulled out continuously.

The yield of polymer by this process is only 25% to 50% because much unreacted material is carried away upon the film. The products may be isolated and purified as for the stirred systems.

* Gel is used to indicate a swollen, pliable, noncrosslinked, noncrystalline polymer precipitate. Crosslinked, insoluble polymers may be prepared by this method, as well as in a stirred system, by simply using intermediates which contain three or more reactive groups (Ref. 37). Superficially such network polymers appear little different from linear polymers.

TABLE I—Typical Interfacial Polycondensations from the Literature

Polymer Type	Organic Solvent Phase	Aqueous Phase	Polymer Yield	Polymer Solution Viscosity (ηinh)*	Reference
Amide,					
Aliphatic	4.78 g. Sebacoyl chloride 336 ml. Carbon tetrachloride	2.32 g. Hexamethylenediamine 1.60 g. Sodium hydroxide 200 ml. Water	90	2.06 (*m*-cresol)	1
Aliphatic	4.78 g. Sebacoyl chloride 60 ml. Dichloromethane	1.20 g. Ethylenediamine 1.60 g. Sodium hydroxide 200 ml. Water	80	1.2 (*m*-cresol)	41
Aliphatic-Aromatic	10.15 g. Terephthaloyl chloride 50 ml. Dichloromethane	6.27 g. *trans*-2,5-Dimethylpiperazine 10.6 g. Sodium carbonate 150 ml. Water			32
Aliphatic-Aromatic	1.27 g. Terephthaloyl chloride 100 ml. Dichloromethane	0.46 g. Propylenediamine 0.81 g. Potassium hydroxide 450 ml. Water	89	0.89 (H_2SO_4)	1, 52
o-Phthalamide	10.15 g. Orthophthaloyl chloride 50 ml. Chloroform	6.5 g. *trans*-2,5-Dimethylpiperazine 4.0 g. Sodium hydroxide 1.0 g. Sodium lauryl sulfate 190 ml. Water	82	1.66 (*m*-cresol)	29
Urea (Carbamide)	4.95 g. Phosgene 200 ml. Carbon tetrachloride	5.80 g. Hexamethylenediamine 4.00 g. Sodium hydroxide 70 ml. Water	70	0.93 (*m*-cresol)	1
Urethane,					
Aliphatic	8.6 g. Tetramethylene bischloroformate 100 ml. Toluene	3.52 g. Tetramethylenediamine 6.36 g. Sodium carbonate 100 ml. Water	80	1.29 ([η]; *m*-cresol)	59
Aliphatic	9.35 g. Ethylene bischloroformate 150 ml. Benzene	4.73 g. Piperazine 10.6 g Sodium carbonate 2.0 g. Sodium lauryl sulfate 250 ml. Water	75	1.6 (*m*-cresol)	69
A-B	1.0 g. 3-γ-Piperidylpropyl chloroformate *p*-toluenesulfonate 5 ml. Dichloromethane	42 g. Sodium carbonate 200 ml. Water	98	0.81 (*m*-cresol)	47
Sulfonamide	6.88 g. 1,3-Benzenedisulfonyl chloride 200 ml. Dichloromethane	3.02 g. Hexamethylenediamine 5.3 g. Sodium carbonate 2.0 g. Sodium lauryl sulfate 200 ml. Water	70	2.2 (H_2SO_4)	58
Phenyl ester	29.5 g. *Bis*(4-chlorocarbonylphenyl) ether 0.5 g. Triethylbenzylammonium chloride 100 ml. Dichloromethane	22.8 g. 2,2-*Bis*(4-hydroxyphenyl) propane 8.0 g. Sodium hydroxide 200 ml. Water		0.76 ([η]; dichlorethane)	8
	71.5 g. Phosgene (added over 2 hours) 600 ml. Dichloromethane 3.0 g. Triethylbenzylammonium chloride (added after phosgene; stir 1 hour)	68.8 g. 2,2-*Bis*(4-hydroxyphenyl) propane 56.1 g. 4,4'-Dihydroxybiphenyl 0.12 g. Sodium dithionite 70.5 g. Sodium hydroxide 700 ml. Water			51c
	5.08 g. Isophthaloyl chloride 5.08 g. Terephthaloyl chloride 150 ml. Toluene	11.40 g. 2,2-*Bis*(4-hydroxyphenyl) propane 4.0 g. Sodium hydroxide 3.0 g. Sodium lauryl sulfate 330 ml. Water	95	1.62 (s-tetrachloroethane-phenol, 40-60)	10

* ηinh = (ln ηr)/c, where ηr is the relative viscosity number and c is 0.5, the concentration of polymer in g./100 ml. solution. The temperature was 30°C.

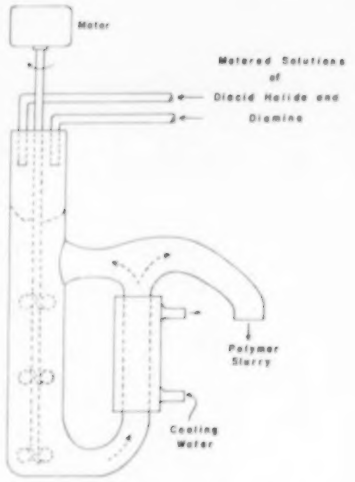


Figure 1. Continuous polymerizer.

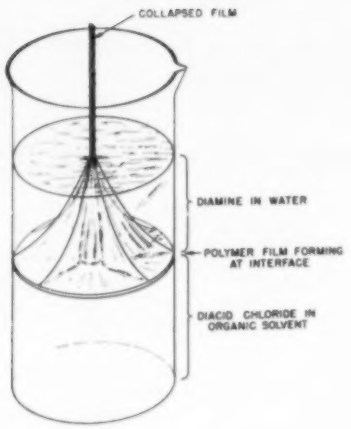


Figure 2. Diagram of an unstirred interfacial polycondensation.

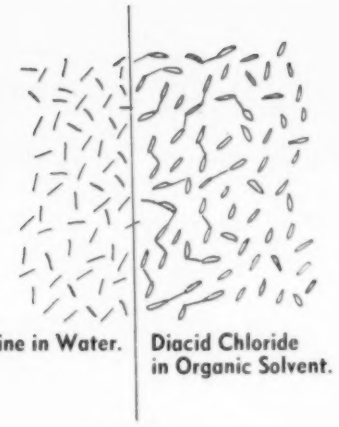


Figure 3. Diagram of early relationship of reactants in interfacial polyamidation.

Mechanism and Nature of the Polymerization (Ref. 41)

The nature of the polymerization process is most readily shown by considering first the formation of an aliphatic polyamide in an unstirred system using a nonsolvent for the polymer as the organic phase. The chemical reaction is shown in Eq. 3. When the phases are brought together, a film of polymer appears at once at the interface as set forth in the preceding section. Under the right conditions this polyamide will have reached high molecular weight in a fraction of a second.

Interface Function: Direct and indirect evidence points to the formation of most condensation polymers in the organic phase. The primary functions of the aqueous phase are to serve as a solvent medium for the diamine or *bis*-phenoxide and the acid acceptor and to remove by-product acid from the polymerization zone. It is believed that the interface has no special orienting or aligning effect on the reactants, but it does provide, through solubility differences, a controlled introduction of the aqueous reactant into an excess of diacid halide in the organic phase next to the interface.

Amine Acylation: Upon phase contact both reactants and solvents tend to become partitioned with the opposing phase. The diamine nearly always has an appreciable potential partition toward the organic phase, whereas the acid chloride has very little solubility in water. Measured equilibrium partition coefficients for diamines in useful solvent systems have varied from 400 to less than one ($C_{H_2O}/C_{solvent}$). The values have been used to estimate the relative tendency of diamines to transfer to the organic phase under polymerization conditions.

Partition equilibria are never achieved during polymerization because acylation takes place in the organic phase as rapidly as diamine is transferred. The mass transfer of the diamine is the rate-controlling step at all concentrations. Were this not so, the diamine would have time to penetrate more deeply into the acid chloride layer and reaction and polymer precipitation would take place more diffusely.

During polycondensation, the first diamine meets a high concentration of acid chloride and presumably is acylated to a large extent at both ends. The following diamine finds a layer of acid chloride-terminated oligomers plus diacid chloride. See Fig. 3. The reaction proceeds by an irreversible coupling of the oligomers by the diamine. The concentration and size of oligomers increases until a layer of high polymer is obtained. Thus, high polymer forms because of the high reaction rate and the increasing probability that diamine reacts with an oligomer rather than new diacid chloride.

During this period of rapid reaction, there is presumably some diffusion of oligomers toward the organic phase along with incoming diamine while from the side of the organic phase there is an entry and reaction of some diacid chloride. The diffusion of polymer chains is relatively slow. To get the highest polymer, the balance of transfer rates must be such as to enter equivalents of reactants in the polymerization zone just within the solution period. For this reason, the system is sensitive to those factors which change the transfer rate of diamine to the organic phase as well as to changes in reaction rate and solvent swelling of the polymer.

Since the reaction is appreciably exothermic, local movement may be increased by the thermal energy imparted to the reactants and solvent molecules. Much of this energy is absorbed by the solvents.

As an extension of the preceding mechanism of polymerization, one may consider that the reaction takes place in a series of incremental layers through which the diamine advances from the liquid interface. As before, the reaction rate exceeds diamine flow. A first layer of polymer forms as the amount of diamine becomes equal to the acid chloride. The polymer in this layer becomes capped with amine groups and diamine passes on to the next. In successive layers, the acid chloride concentration is initially higher than that of the diamine. At the same time, the diamine flow drops off because of the increased distance from the interface and the need to penetrate the first layers of polymer. There may exist in the final film a gradation of average molecular weights from face to face which would vary with the original concentration of the reactants.

Acid Elimination: Following the initial fast addition of amine to acid chloride, hydrogen chloride is eliminated in a still faster step and transferred to the aqueous phase. Elimination and transfer of the proton and chloride ion are presumed to occur with the assistance of water or amine. The hydrogen chloride is retained in the aqueous phase as the diamine salt or it may be neutralized there by an inorganic base.

Acid Chloride Hydrolysis: Experiments have shown that acid chloride hydrolysis takes place exclusively in the aqueous phase. Hydrolysis may be by water alone or by the faster reaction with hydroxyl ion. Most diacid chlorides have low solubility in water and so are protected from hydrolysis. The shorter chain aliphatic diacid chlorides are the most water-soluble and are hydrolyzed to the greatest extent as shown by lowered yield. Hydrolysis also becomes a more important competitive reaction when the polycondensation rate is low. Since the hydrolysis products are highly water-soluble salts, they are withheld from the polymerization zone by the aqueous phase.

Precipitation: As the concentration of polymer species increases, interchain contacts increase until a contact network is formed and precipitation results. Morgan and Kwolek have proposed that there is a finite and rather reproducible solution period which increases with the strength of the interaction of the polymer and solvent. Further, the initial gel is more open or less compact as the polymer-solvent interaction increases. These two factors provide a variation in the polymerization time with the nature of the solvent.

At the point when a coherent film is formed, polymerization does not entirely stop but is greatly decreased in rate because of the lower mobility of the polymer chains and the decreased diffusion rate of the intermediates. While the initial polymer reaches the maximum molecular weight permitted by its degree of freedom in the gel and the availability of new reactants, there is a secondary growth of low polymer in the spaces of the gel and upon the face of the film in the organic phase. This leads to a lowering of the average molecular weight and a broadening of molecular weight distribution.

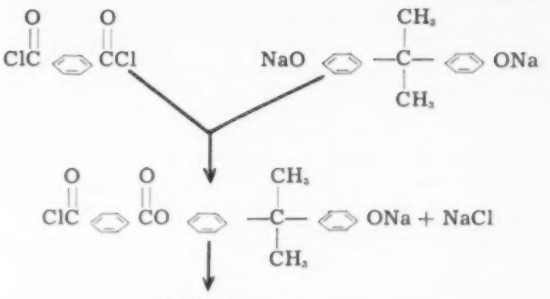
Stirring: The mechanism for stirred polymerizations is the same as for unstirred except that stirring assists the transfer of reactants and by-products. When thin films form about the droplets of reactant solution, they may be torn away and fresh surface exposed for renewed reaction. When the polymer remains in solution, the mechanism is likewise the same but now the possible period of active polymerization is extended. The concentration ratio of the phases may be less important unless acid chloride hydrolysis interferes. Stirring need not be vigorous when the polymer remains in solution, but it must be adequate to distribute equivalents of aqueous reactant to every droplet of polymer solution.

Polycondensations Other Than Polyamidation: Thus far, the discussion has been concerned with polyamidation. The principles which apply to it apply with little modification to all other fast condensations employing diamines in the aqueous phase, such as the preparation of polyurethanes and polysulfonamides.

Reactions which do not eliminate a by-product, such as the formation of a polyurea from a diisocyanate and a diamine, have also been shown to proceed on the organic solvent side of the interface.

The formation of poly(phenyl esters) differs from polyamidation in several respects. First, the reaction of bisphenols with a diacid halide is a slow reaction at room temperature unless the phenol is in the form of the phenoxide ion. Furthermore, the formation of the *bis*-phenoxide ion is usually necessary in practice in order to attain sufficient solubility for the phenolic intermediate in the aqueous phase.

(Eq. 4)



The illustrated reaction is believed to proceed by a nucleophilic attack of phenoxide on acid chloride.

The *bis*-phenoxide has high solubility in the aqueous phase and very little solubility in the organic phase. Therefore, in this polymerization the diacid chloride must approach the liquid interface for a reaction to take place. Because of this requirement of reaction at the liquid interface, solvents or near solvents for the polymer are necessary in order to provide continued mobility for the oligomers and permeability for the diacid chloride. Conix, Fox and Schnell (Refs. 8, 16, 50) each report that quaternary ammonium salts and bases assist the polymerization. Although these reagents have been spoken of as catalysts, the improvement probably results from the formation of organic solvent soluble phenoxides and subsequent transport of the chloride ion to the aqueous phase as the quaternary ammonium salt. Small amounts of sulfonium salts (Ref. 8) and tertiary amine salts (Ref. 3) and bases also have been used as accelerators of polyesterifications.

An examination of the unstirred interfacial polycondensation of 2,2-*bis*(hydroxyphenyl)propane and alkali with terephthaloyl chloride showed that the polymer film formed in the organic phase (Ref. 41). The initial film continued to expand some within its original surface boundaries. Much of the additional growth was on the face adjacent to the liquid interface and there was no growth on the surface in the organic phase.

This picture of the mechanism is in accord with the findings of Eareckson (Ref. 10) that poly(phenyl esters) are best prepared in solvents or near solvents in rapidly stirred systems with detergents. Such a method provides small droplets and large surface areas about which the reaction may occur. Thereby, as much forming polymer as possible is kept in contact with the interface and the obstruction to the passage of acid chloride is kept at a minimum. Since the acid chloride must react at the interface and be exposed to a high concentration of hydroxyl ions, the less readily hydrolyzed aromatic acid chlorides yield higher polymers than the aliphatic acid chlorides.

Selection of Optimum Polymerization Conditions

Interfacial polycondensation is subject to the effects of many variables. Some of the more important are listed in Table II and their effect is indicated in the section on the polymerization mechanism. The relative importance of these variables may differ with the polymer system, but in general the first three, reaction rate, purity and adequate swelling or solubility of the polymer, are of prime importance.

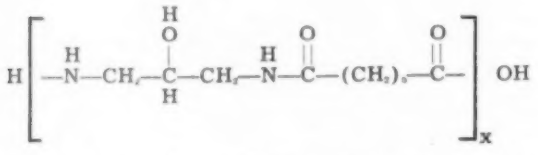
A proper balance of the concentration of intermediates in the two phases is often important as shown for several polyamides in Fig. 4 (Ref. 41). At the peaks not only is the inherent viscosity number at a maximum but the amine and carboxyl ends are nearly equal and at a minimum in proportion to the viscosity number. This means that the molecular weight distribution is narrowest at the peak viscosity. The same effect has been apparent in stirred systems although the curves are usually broader. Fig. 5 shows the relation of viscosity number and reactant concentration for a polysulfonamide.

Optimum points in inherent viscosity are found upon changing other variables also. There is a maximum associated with increasing the solubility of the polymer. Jones and McFarlane (Ref. 28) have reported a maximum in yield and molecular weight in the preparation of polyurethanes when the pH of the aqueous phase was held at 11.5. Still other preferred conditions may be found by varying the stirring rate, the use of detergents, and selecting the best solvents (Refs. 10, 36, 41).

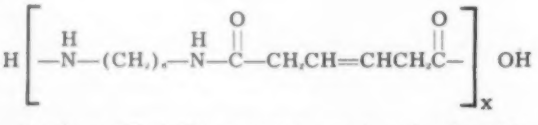
Polyamides

Polyamides are by far the easiest polymers to prepare by interfacial polycondensation. This class is the most tolerant of solvent changes, deviations in purity of intermediates, intermediate and solvent ratios and of excesses of acid acceptors (Refs. 1, 70). Wide variations in equipment are acceptable. Despite this the literature on polyamides by interfacial polymerization is quite limited. Kirby (Ref. 30) reacted diamines with adipoyl *bis*(*ortho*phosphoric diesters). The preparation of polyamides from diacid halides has been described in patents by Jones and McFarlane (Ref. 24d), Magat and Strachan (Refs. 36, 37), Langsdorf and Wittbecker (Ref. 32) and Campbell (Ref. 5). Recent papers from this Laboratory (Refs. 1, 41, 70) have discussed the preparation and mechanism of formation of polyamides in considerable detail. Much of this data is reviewed elsewhere under mechanism, variables, and experimental examples.

Structural Variations: Examples presented by Beaman et al (Ref. 1) show that the process may be used to prepare conventional polyamides such as 6-6 nylon. At the same time others may be made in high quality which are not accessible in any other way. Examples are the polyamide from piperazine and bibenzoic acid which melts above 400°C, the polyamide from 2-hydroxypropane-diamine and sebacic acid,



and the polyamide from hexamethylenediamine and β-hydromuconic acid.



Stephens (Ref. 57) reported a series of polyamides derived from 4,4'-sulfonyldibenzoic acid and Shashoua (Ref. 52) has made a variety of polyamides from ethylenediamines and other short chain diamines, which cannot be made by the melt method.

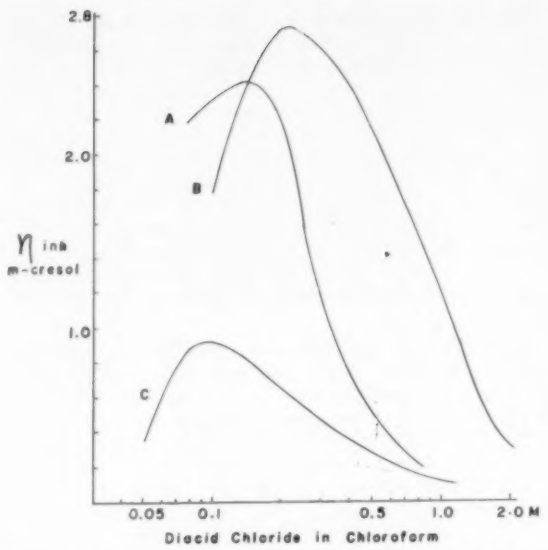


Figure 4. Polyamides by unstirred interfacial polycondensation. A. Poly(terephthaloyl piperazine); B. Poly (hexamethylene sebacamide); C. Poly(hexamethylene terephthalamide); diamines, 0.4M.

TABLE II

Some Variables Affecting Interfacial Polycondensation

1. Chemical reaction rate.
2. Purity of intermediates and solvents.
3. Precipitation rate of the polymer-degree of swelling or solubility).
4. Transfer rates of reactants and by-products.
5. Concentration ratio of reactants in the two phases.
6. Concentration level in the system.
7. Hydrolysis of acid halides.

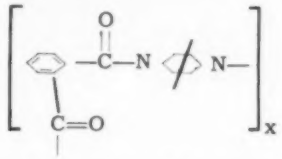
Polyureas, which are polyamides of carbonic acid, and o-phthalamides are reviewed below.

Polyureas: Polyamides of carbonic acid have been made by numerous routes (Ref. 21). Of these, several low temperature methods are known. The most used is the reaction of a diisocyanate with a diamine. This may be carried out in a two phase system but, since there are no by-products, single solvents such as phenols and alcohols are commonly employed. Wittbecker (Ref. 68) has applied the interfacial method for the reaction of phosgene or thiophosgene with a diamine (see Table I for an example). A third route described by Lyman and Jung (Ref. 35) is to react a *bis*-carbamyl chloride with a diamine. This type is discussed under ordered copolymers.

o-Phthalamides: Both terephthalic and isophthalic acids and their derivatives have been used successfully in the preparation of fiber-forming polyamides and polyesters by melt methods. The acid chlorides may also be used to make certain esters and amides by interfacial polycondensation (Refs. 1, 10, 70). Phthalic acid on the other hand, yields only low melting or low molecular weight *linear* polymers by the melt method. The difficulty presumably arises

from the proximity of the reactive groups and the greater posibility of ring closures and side reactions.

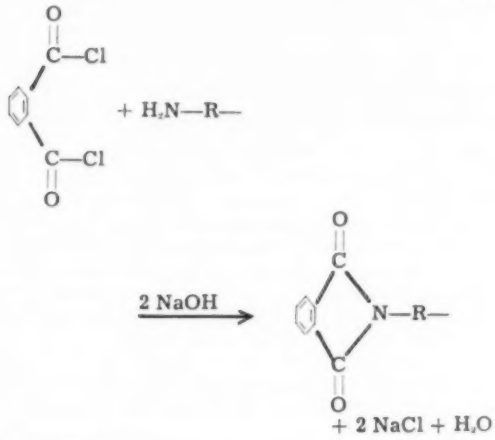
In interfacial polycondensation, Katz (Ref. 29) has found phthaloyl chloride will form high melting, high molecular weight polyamides with secondary diamines. Particularly useful diamines are the piperazines, as illustrated below.



Polymers of this type have inherent viscosity numbers from 1 to 2 and melt above 325°C.

o-Phthaloyl chloride and primary diamines yielded polymers with only moderate molecular weights. This is presumably because chain termination results from imide formation.

(Eq. 5)



Polyurethanes

Polyurethanes which melt above 200°C cannot be made by a melt method or fabricated by melt extrusion because of decomposition. There are two major low temperature routes to polyurethanes, (1) a diisocyanate plus a glycol and (2) a *bis*chloroformate plus a diamine. Both of these processes were studied and developed in Germany in the period around 1940 (Refs. 21, 53, 54), primarily for the preparation of wholly aliphatic polyurethanes. The isocyanate method, which was not carried out as a two-phase process, was preferred because narrower molecular weight distributions were obtained. Many patents appeared, following World War II, describing both processes. A few relating to the interfacial method are listed (Refs. 20, 43, 44, 62). Since that time Jones and McFarlane (Refs. 24, 28) studied the interfacial preparation of aliphatic polyurethanes and were able to make a number of process improvements as well as define the effects of a number of variables such as the pH of the aqueous phase and the reaction time. Recently, Wittbecker and Katz (Refs. 67, 69) have improved and broadened the application of interfacial polycondensation still further. They have shown that the method is applicable to nearly every type of diamine and to bischloroformates of aliphatic glycols, cyclohexylene glycols and *bis*phenols. Of special interest were polyurethanes from piperazines. Many piperazine polyurethanes melt well above 200°C and yet are soluble in common solvents such as chloroform or formic acid. The diisocyanate route cannot be used for these urethanes because an isocyanate cannot be formed from a secondary diamine.

A recent patent of Reuber (Ref. 46) describes polyurethanes bearing sulfonic acid substituents prepared from intermediates such as 1,4-diaminobenzene-2-sulfonic acid.

Polysulfonamides

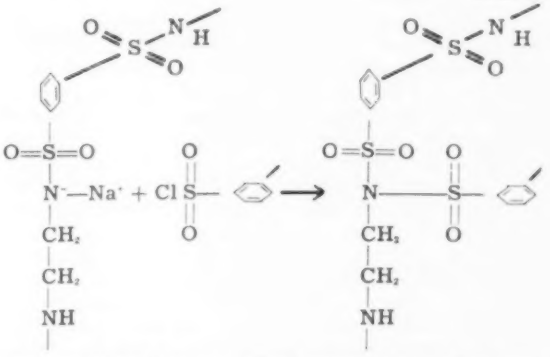
There are numerous references in the literature to the preparation of polysulfonamides (Refs. 2, 21) but none of these appear to have led to high polymers until the work of Jones and McFarlane in 1954 (Ref. 24c). Recently, Sundet, Murphey and Speck (Refs. 55, 58) described similar work. Both of these groups used low temperature, interfacial polycondensation as the successful procedure.

The latter group report that the method is particularly applicable to aromatic and aliphatic disulfonyl chlorides with primary aliphatic diamines. Critical factors were the use of highly purified disulfonyl chlorides, a careful balance of phase concentrations and the avoidance of high pH in the aqueous phase (Fig. 5). Detergents were helpful and elevated temperature reduced the molecular weight.

Polysulfonamides prepared from primary diamines contain an amide hydrogen which is acidic. Like the polyamides they dissolve in such powerful solvents as *m*-cresol and sulfuric acid. However, the polysulfonamides are normally soluble to high concentrations (20-30%) in electron-donor solvents such as dimethylformamide and pyridine as well as in 10% aqueous sodium hydroxide, while polyamides dissolve more readily in acidic solvents such as concentrated formic acid. This is consistent with the acidic character of the sulfonamide group, and the predominant nucleophilic nature of the carbonyl oxygen in the carbonyl group.

The tendency to dissolve in alkali leads to an unusual difficulty during polymerization. When the basicity of the aqueous phase was allowed to be high, there was not only an increase in hydrolysis of the sulfonyl chlorides but a formation of branched and cross-linked polymers. The latter occurred because of the formation of an amide anion which is readily acylateable by the sulfonyl chloride.

(Eq. 6)



Such an effect has not been reported for other condensation polymers.

A-B Polymers

Interfacial polycondensation has been used to prepare high polymers from A-B intermediates by

Schaefgen, Koontz and Tietz (Ref. 47). An A-B intermediate is one which contains both complementary reactive groups in the same molecule.

(Eq. 7)

$$x\,ClCO(CH_2)_5NH_2\cdot HCl \xrightarrow{NaOH} \left[-CO(CH_2)_5NH-\right]_x + 2x\,NaCl$$

Polyamides and polyurethanes have been prepared but polysulfonamides, polyureas and other polymers could be prepared as well.

In order to prevent polymerization during the preparation of the intermediate one of the functional groups must be masked. This is readily done with an amine group by keeping it in the form of a salt such as a hydrochloride or toluenesulfonate, as shown in Eq. 7.

Aminoacid chloride hydrochlorides were synthesized years ago by Emil Fischer (Ref. 13) and they have been recently used to form low polymers in a single phase system by Frankel, Liwschitz, and Zilkha (Ref. 17). There is also one reference to the use of 5-aminopentyl chloroformate salts by the interfacial method (Ref. 53).

Several difficulties are peculiar to the use of A-B intermediates in interfacial polymerization. The intermediates are salts, but because of the presence of the acid halide function, they must be recrystallized from inert solvents, which in turn are poor salt solvents. This solubility difficulty is also encountered in seeking a suitable organic phase for the polymerization. Several chlorinated aliphatic hydrocarbons, such as dichloromethane, chloroform and 1,2-dichloroethane, have worked well. The polymerization is carried out by contacting a solution of the intermediate in an organic solvent with an aqueous solution of alkali. The alkali frees the amine function and also accepts the by-product acid from the polymerization. There is a great tendency for the salts of the A-B intermediates to be partitioned into the aqueous phase, whereupon considerable hydrolysis of the acid halide function occurs with consequent loss in yield. This was overcome to a considerable extent by using high concentrations of inorganic salt, alkali or potassium carbonate in the aqueous phase to reduce the monomer solubility.

The formation of high polymer in the A-B system is not dependent upon having equal quantities of two intermediates entering the polymerization zone as is the A-A plus B-B system. However, the single intermediate or an oligomer chain end bearing salt must reach the interface to become "activated." This step is brought about by concentrating the organic phase, providing a polymer solvent if possible, and increasing the interfacial surface area by rapid stirring and use of detergents.

Poly(phenyl esters)

Polyesters were possibly the first polymers to be prepared from diacid chlorides, for Vorländer (Ref. 63) prepared low molecular weight polyethylene succinate in 1894 and Einhorn (Ref. 12) prepared poly(phenyl carbonates) in 1898. Carothers (Ref. 38) started his studies on condensation polymers with polyesters. Most of these early linear polyesters had wholly aliphatic structures or had low molecular weights and as a result were low melting and of

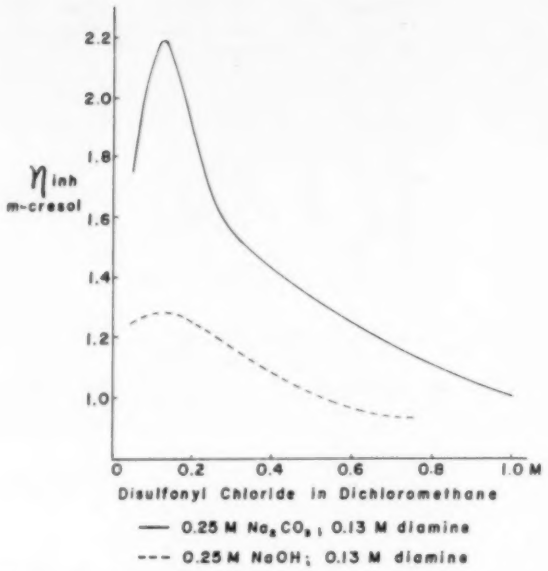


Figure 5. Preparation of the polysulfonamide from *m*-benzenedisulfonyl chloride and hexamethylenediamine.

limited technical interest. The higher melting polyesters derived from aromatic diacids and aliphatic glycols, such as polyethylene terephthalate, have since been prepared by the high temperature methods of ester exchange (Refs. 21, 22, 66) and other related polyesters have been made by direct reaction of the diacid chloride and glycol (Refs. 15, 34). The ester exchange method is used commercially on a large scale.

During the past few years poly(phenyl esters) of carbonic acid (Refs. 16, 50, 51) have received considerable attention. These polymers have been made in high molecular weight. They are tough, clear, low in color and many may be molded or spun from the melt. Some of the poly(phenyl carbonates) are undergoing large scale evaluation (Refs. 7, 61).

Several routes to poly(phenyl esters) have been described. These include (1) an acid exchange reaction in which the acetate ester of a *bis*phenol reacts with a dibasic acid (Refs. 9, 65), (2) a high temperature ester exchange between a diaryl carbonate and a *bis*phenol (Refs. 16, 51d), (3) the reaction of a *bis*phenol with phosgene in pyridine with or without a diluent (Refs. 16, 50) and (4) interfacial polycondensation of a diacid halide with a *bis*phenol in alkali (Refs. 8, 10, 16). A popular type of bisphenol has been 2,2-*bis*(4-hydroxyphenyl)propane and its homologs. (See Eq. 4.)

There are several variations of the two-phase polymerization method for poly(phenyl esters). All appear to be equally successful. All employ the bisphenol in the form of its phenoxide ion.

(a) Diacid chloride in a solvent for the polymer. This feature may be combined with one of the variations below.

(b) Diacid chloride in a polymer solvent or swelling agent plus a small amount of a quaternary ammonium or sulfonium salt or base or a tertiary amine (see section on mechanism). The quaternary ammonium compound may be added to the initial acid chloride solution

(Ref. 8) or after partial formation of the polymer (Refs. 3, 50).

(c) Process similar to (b) but conducted under nitrogen and with a reducing stabilizer, sodium dithionite (Ref. 51b).

(d) Process similar to (b) but conducted in the presence of a tertiary amine plus a surface active agent (Ref. 51e).

(e) Diacid chloride in a polymer solvent or swelling agent in a system employing a detergent and high-speed stirring (Ref. 10).

Each of the variations provides for the continuation of the polymerization in some way. This is accomplished by keeping the polymer dissolved or highly swollen, increasing the surface contact of the phases, or providing a phenoxide which is more soluble in the organic solvent phase. Eareckson (Ref. 10) found that in a given solvent system copolymers formed in higher molecular weights than homopolymers. This is a reflection of the greater solubility of the copolymers. When the toluene used in the polymerizations was replaced by 1,1,2-trichloroethane, the viscosity of the homopolymers was increased threefold.

Some substituents in the phenolic intermediate, such as the electron-withdrawing sulfonyl and carbonyl groups, reduce the reactivity of the phenoxide and make polymer preparation more difficult. Schnell, Krimm and Bottenbruch (Refs. 51e, 51f) reported the preparation of copolyesters in which part of the *bis*phenols contained sulfoxide and sulfone groups. Schnell and Bottenbruch (Ref. 51a) also made polycarbonates with carboxyl substituents. Aliphatic diacid chlorides were used by Eareckson to form poly(phenyl esters) with fair molecular weights. Aliphatic glycols did not perform well in interfacial polymerization because of their low reactivity and excessive hydrolysis of the acid chlorides. However, Murphey (Ref. 42) was able to make polyesters with high molecular weight from the more reactive dithiols.

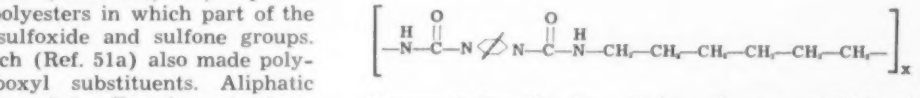
Ordered Copolymers (Ref. 35)

Condensation copolymers are of two principal types: (1) those in which the functional groups are varied as in a polyester-amide and (2) those in which the structures in one type of intermediate are varied as by the use of two different dibasic acids or diamines. The overall distribution of the functional groups and intermediate types would be random in a melt polymerization because this process is carried out under conditions such that there is free interchange of species. By the use of special techniques, such as melt blending (Ref. 4) or by using macrointermediates containing noninterchangeable groups (such as polyethylene glycols) (Ref. 11), condensation polymers with ordered or block arrangements have been prepared. These ordered arrangements lead to differences in physical properties, just as has been demonstrated in recent years through the preparation of block and graft copolymers in the addition polymers.

Interfacial polycondensation readily yields copolymers ranging in order from alternating to block type since no redistribution of groups will take place at the low polymerization temperature. For other reasons, however, completely random copolymers are probably not usually obtained from mixed reactants.

Factors contributing to unintentional order are differences in the reaction rates of pairs of intermediates and the differences in transfer rate of the aqueous reactants to the polymerization site in the organic phase. The polymer may approach random structure if the polymer remains in solution and the rate differences are small. Many systems form polymer and polymer precipitates extremely rapidly. Solubility differences enhance the tendency to form blocks of one polymer type capped or linked with the second type. A combination of the above circumstances can lead to the formation of a high proportion of homopolymers. The nonrandomness or ordering also may be purposely influenced by the manner in which the reactants are added to the polymerization. A final consideration relating to copolymerization is that the copolymer may not have the composition of the charged materials because of losses by hydrolysis and incomplete reaction.

Copolymers have been described in many of the literature references on interfacial polycondensation. None of these references discuss the possible nonrandom nature of these products. Alternating copolymers which start with preformed chain links of various types have been set forth in numerous French and German patents (Ref. 43). The majority of these are not well characterized. Lyman and Jung (Ref. 35) prepared the alternating copolyurea shown below by first making 1,4-piperazine dicarbonyl chloride and reacting it with



hexamethylenediamine. This polymer melted at 265°C and was crystalline whereas the random polymer from the two diamines and phosgene was amorphous and melted at 194°C.

Lyman and Jung further prepared and characterized the block copolymers from terephthaloyl chloride, ethylene *bis*chloroformate and *trans*-2,5-dimethylpiperazine. The solubilities of the homopolyamide and homopolyurethane were such that they could be removed from the copolymers. Differences in the reaction rates of the acid chlorides, added to the reaction simultaneously, led to a finely ordered structure which had only lateral lattice order by X-ray (Ref. 56), whereas changes in the order of addition of the acid chlorides gave block copolymers with longitudinal lattice order.

Molecular Characteristics

Wherever it has been possible to compare polymers made by interfacial polycondensation with the same polymers made by melt polymerization, there have appeared no unexpected differences. They are the same in melting point, crystallinity and crystalline form by X-ray pattern and in solubility. Both methods yield essentially linear polymers when the intermediates are purely bifunctional. Exceptions of branching and network formation appear in the polysulfonamides by interfacial polycondensation and related cross-linking may occur in polymer melts as a result of degradative reactions.

The normal melt polymerization yields a random distribution of molecular species complying with rules first described by Flory (Ref. 14) and later experimentally demonstrated by Taylor (Ref. 60). In interfacial polycondensation the system is far from thermal equilibrium and the reaction is most often heterogeneous in several respects. Although high

average molecular weights are readily attained, more often than not the distribution of molecular weights is not random in the Flory sense. In many cases the distribution is broader than random but there are indications that special circumstances may give rise to narrower than random distributions. The broadening effect is frequently due to the presence of a low molecular weight fraction which forms as "secondary" polymer in and on the initial polymer precipitate (Refs. 39, 41, 50). Little has been reported on harmful effects on physical properties which might be attributed to the presence of a low molecular weight fraction in products formed from interfacial condensation polymers. Miller (Ref. 39) did find that polyurethanes with improved thermal stability were obtained when the polymerization was stopped at 90% completion. If polymers with broad molecular weight distributions are held at high temperature in a molten state, equilibration of molecular species occurs and the viscosity drops.

An interesting feature of interfacial polycondensation is that it often produces polymers with higher molecular weights than have previously been known in the condensation polymer field. Schnell (Ref. 50) reports polycarbonates with $\overline{M}_n$ up to 200,000; Conix (Ref. 8) has made polyphenyl esters with $\overline{M}$ up to 250,000; Wittbecker and Morgan (Ref. 70) described polyurethanes with $\overline{M}_w$ by light scattering up to 10^6. It remains to be seen what new properties will be associated with these super polymers.

Interfacial Versus Melt Polycondensation

Table III presents a summary comparison of interfacial and melt polycondensation.

Interfacial polycondensation is a versatile process which has opened the way to the preparation and evaluation of many polymers which were not previously accessible by the melt method. With a minimum of equipment the polymer chemist can now make polymers rapidly and in high quality. Many intermediates considered useless in the past can be converted to polymers with new and interesting properties. Since many of the polymers which can be made by interfacial polycondensation are infusible or thermally unstable, shaping and extruding by other means than melting may be required, such as with solvents or plasticizers. Although interfacial polycondensation is readily scaled up or made continuous, it must be borne in mind that large quantities of solvents are used and much by-product salt is formed.

TABLE III

Comparison of Interfacial and Melt Polymerization

	Interfacial	Melt
Intermediates		
Purity	Moderate to high	High
Balance	Tolerant of wide deviations	Necessary
Stability to heat	Unnecessary	Necessary
Polymerization Conditions		
Time	Several minutes	Several hours
Temperature	0-40°C	> 200°C
Pressure	Atmospheric	High and low
Equipment	Simple, open	Special, sealed
Products		
Yield	Low to high	High
Structure	Extremely wide range	Limited by stability to heat and fusibility
By-products	Salt	Water or volatile organic compounds

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* These papers will be published in forthcoming issues of the Journal of Polymer Science.

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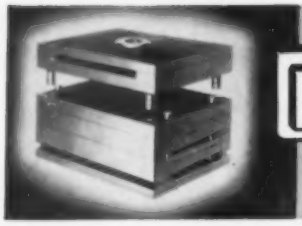

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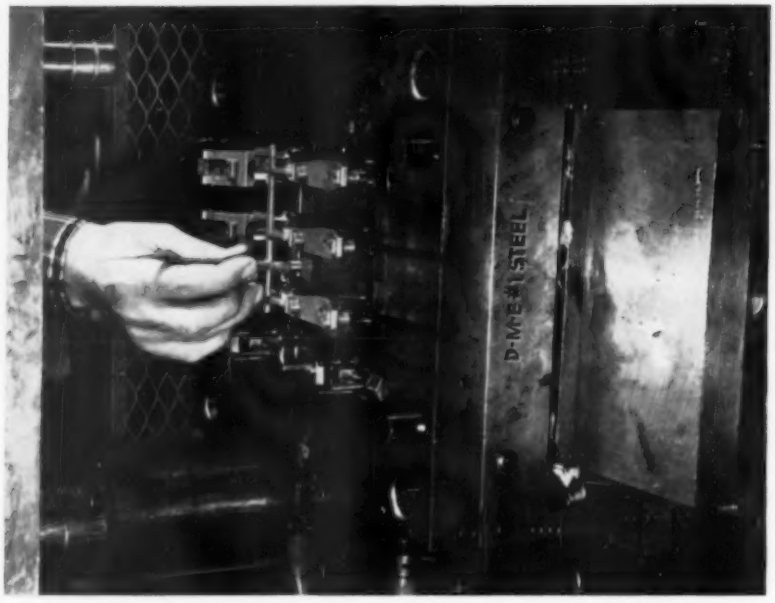

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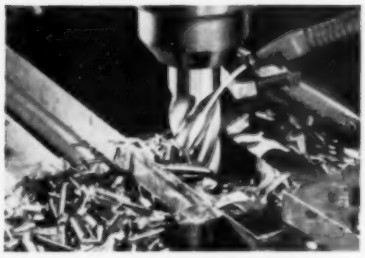

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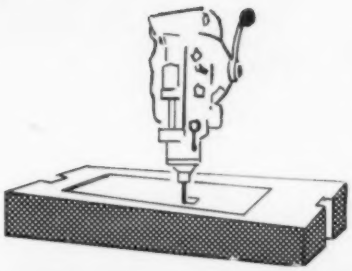

Edited by **Ernest J. Csaszar**
Sales Manager, Newark Die Company, Inc., Newark, N. J.

MOLDMAKING

Let's Get the Facts on Moldmaking

Ernest J. Csaszar

This is the first of feature articles specifically dealing with technical information in the field of moldmaking. It is our hope that this feature might act as a clearing house for interesting facts or ideas regarding the design and construction of molds for the plastic industry. The information that would be published in this column would come from you, our readers, and those contributing would receive in exchange, ideas from other contributors. It is perhaps hackneyed to say that you will get out of this column what you put into it, but we believe it is worth repeating. It is always difficult to get people to offer information that they feel might give them some private advantage over someone else. If this feature, even in a small way, can break through the barrier of false secrecy, we can consider this a big step towards the distribution of technical knowledge. This is exactly what we would like to do; encourage those concerned to exchange ideas with one another. It has been proven many times over that those giving information often receive more in return.

How does one get to be a leader in any particular field of endeavor? Certainly leadership is measured by performance. Specific performance is all too often limited to an activity's immediate surroundings. In order to get people to know that you do something well, you have to, to a degree, tell them what you know. This does not mean that someone must reveal the innermost secrets involved in their specialty. We must, however, let people know enough so that they can evaluate the degree of our knowledge.

If we take our livelihood from a specific field of endeavor, we will find that we can not continue to draw upon this, without in some way replenishing the supply. The contribution and exchange of knowledge within an industry or branch of an industry is what makes it grow. It follows then, as the industry grows, those of us in it, grow along with it.

It is based on this type of reasoning that we would hope to encourage the readers and authorities on moldmaking to contribute material for the free exchange of information on this subject in this feature.

May we suggest some of the topics that are timely and about which the least is generally known. If we were to consider injection molding from a point of view of molding construction, we might say something new has been added of late. In the development of molding machinery and automatic molds we find that molding cycles are more and more being limited by the speed with which we can cool the molded article. In this respect, ideas on novel methods of rapid cooling would indeed be a help to our readers. Other topics that might be of considerable interest are as follows:

Design features on molds for:

1. blow molding,
2. expanded foams,
3. premix compounds,
4. matched material for reinforced plastics.

Let us get a good start for our first column with technical data. Please get your information to us (or questions, if you prefer) and we shall try to get the answers for you.

ONTARIO SECTION TO HOLD LECTURES ON PLASTICS TECHNOLOGY

October 5, 1959

University of Toronto

During the Directors' meeting of the Ontario Section of SPE, held on May 19th, at the St. Regis Hotel, it was announced that a lecture series on Plastics Technology would commence at the University of Toronto, Extension Dept., on October 5, 1959. The Syllabus covering a two year course has been prepared by the Educational Committee of the Ontario Section of SPE, working under the guidance of Professor W. G. MacElhinney and J. A. McIntyre, of the University of Toronto. J. E. Parkhill, Chairman of the SPE Educational Committee, advises that application forms and literature will be mailed to members of the SPE and SPI before the end of the summer, and may be obtained by interested persons by writing the Director, University Extension, 65 St. George St., Toronto, after June 20th. The SPE Educational Committee responsible for promoting the course consists of the following people: Ken Blakely, Chemical Oil & Resins Ltd.; R. K. Buhr, Canadian Industries Ltd.; J. E. Parkhill, Barnett J. Danson & Associates Ltd.; C. L. Seay, Eastman Chemical Ltd.; Harold A. Shure, Naugatuck Chemicals.

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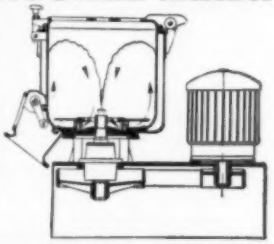

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ASK FOR BULLETIN M1

Edited by **B. H. Maddock**
Union Carbide Plastics Co.

SPEAKING of EXTRUSION

Extrusion of Polypropylene

Russell D. Hanna

Hercules Powder Company
Plastics Technical Service Laboratory

POLYPROPYLENE, a valuable member of the versatile polyolefin family, has been in commercial production in the United States for about 1½ years. The dramatic speed with which polypropylene progressed from a laboratory curiosity to multi-million pound commercial production is already the subject of many reports (Ref. 1), as are the physical and organic chemistry accomplishments made possible by the application of organo-metallic catalysts (Ref. 2). It is not the intent of this paper to discuss these aspects, but rather to broadly report the extrusion techniques which have been found most successful with polypropylene. It will also briefly cover part and die design features preferable in engineering for the use of polypropylene, and finally, several case histories of successful Pro-fax applications will be reviewed.

Rather than attempt to give specific answers to every potential question, it is preferable to generally consider how the physical properties of polypropylene can be expected to affect part and die design; also, how analysis of these properties can aid in establishment of the optimum extrusion conditions for a particular application. Since polypropylene is a new member of the polyolefin family, and is associated in many minds with other more familiar polyolefins, particular care will be taken in pointing out the similarities and dissimilarities of these chemically related but different materials, as well as making generous use of comparisons with other material with which the industry is well familiar.

Condensed from a paper presented at the Fifteenth Annual Technical Conference of SPE in New York City.

DESIGN CONSIDERATIONS

Actually, there are no secret principles which must be strictly adhered to. The same principles applicable to good design in any thermoplastic, and particularly other polyolefins, also apply to polypropylene.

Physical Properties

Foremost, of course, is to establish and fulfill strength and appearance requirements on the basis of the physical properties of polypropylene. Some of the more important properties of primary interest in part design considerations are shown in Table I. In

TABLE I

Typical Properties of Injection Molded Pro-Fax

Specific Gravity (D 792-50)	0.901
Cubic Inches per Pound	30.8
Tensile Strength (D 638-56T)	5,000 psi
Elongation at Yield (D 638-56T)	11-15%
Flexural Strength (D 790-58T)	8,000 psi
Stiffness in Flexure (D 747-50)	175,000 psi
Izod Impact, unnotched (D256-56)	>33 ft.-lbs
Surface Hardness (D 785-51)	95R
Heat Distortion Temperature	
(66 psi) (D 648-56)	221°F
(264 psi) (D648-56)	140°F
Tensile Strength at 212°F (D638-56T)	1,720 psi
Coefficient Linear Thermal Expansion (in./in./°F) (D696-44)	4.7×10^{-5}

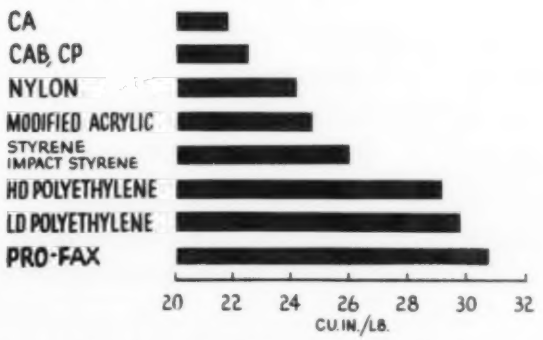

Figure 1. Specific volume of several thermoplastics.

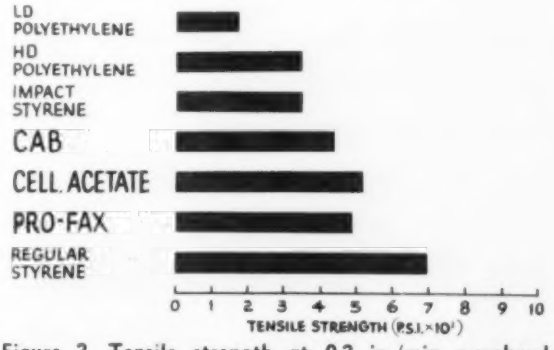

Figure 2. Tensile strength at 0.2 in./min crosshead speed (D 638-56T).

order to relate these mechanical properties with those of other materials, Fig. 1 compares the cubic inches per pound of polypropylene with several other thermoplastics; Fig. 2 compares the tensile properties of these materials; Fig. 3 the stiffness in flexure; Fig. 4 depicts surface hardnesses; and Fig. 5 the heat distortion temperatures at 66 psi. From this table and these graphs, it can be recognized that polypropylene meets the engineering requirements of a wide range of applications presently served by other moderately priced materials. However, it also offers a balance of properties to the design engineer which is not available in any other one material. In addition, properties previously obtainable only through the use of higher priced resins or non-plastic materials are now available in polypropylene to permit design of superior products at lower costs to open broad new markets for our industry.

EXTRUSION

Consideration of the physical properties of polypropylene will serve as a general guide to the suitability of this material in a given application, as well as establishing the basic aspects of engineering design and operational procedures. Again, the fundamental principles of good technique which apply to other thermoplastics, and particularly other polyolefins, also apply to polypropylene. Application of existing extrusion knowledge has already resulted in commercial production of film less than ½ mil thick, 60" wide to 1" thick sheets 48" wide; simple profiles, wire coating and filaments, as well as pipe and tubing from 6½" down to 3/32". This includes, of course, the plastic industry's 1958 equivalent of the gold rush of '49, spinning hoops.

Extruder

Polypropylene can be readily extruded in most existing equipment with no danger of corrosive degradation products. It can be used without drying, since moisture content and pickup are negligible. For greater machine efficiency and uniform quality, however, the use of a hopper dryer set at 180°—200°F is suggested. To provide the most homogeneous melt, cylinders with length-to-diameter (L/D) ratios of at least 16:1 are recommended. Being shear-sensitive, polypropylene reacts well to high-compression screws. A compression ratio of at least 4:1 is preferable. Metering and Dulmage-type screws operate well, with cooling water sometimes being required. Screen packs of at least 60 mesh, preferably 80 and 100 mesh, should be used to build back pressure. Dies with restrictions in the melt channel have been used successfully on extruders which are not adaptable to screen packs. An adjustable valve between the screw and the die could also be used to build back pressure. In general, long land lengths should be considered for dies, from 12½ to 50 times the shapes average thickness. Approach to the land should be long and shallow, with streamlining being important in prevention of turbulence and dead-spots. A taper of 2°-5° in the land seems to aid flow in restricted areas. A taper of up to 10° in the approach area can be considered as part of the "land length".

Sheet Extrusion (20-250 mils)

In the extrusion of polypropylene into sheet, temperatures of 350°—400°F on the rear zone are recommended, with center and front zones set higher so as to give a *melt* temperature of 420°—450°F. Temperatures and die openings should be balanced across the face of the die to obtain uniform flow, with the temperature equal to or slightly less than the melt temperature.

Sheet take-off equipment should provide three rolls with individual temperature control for greatest efficiency, and with surfaces suitable to the type of finish desired. Temperatures of the rolls should be in the range of 180°F, or just below the point where sticking occurs. Drawdown of the sheet (from the die) should not be greater than 10%, with the top roll set to maintain uniform contact pressure, but not so as to build up material in the nip. Cooling should be as uniform as possible, with protection from stray air currents sometimes necessary.

Film Extrusion (Up to 20 mils)

Polypropylene requires somewhat higher stock temperatures than polyethylenes as the thickness decreases in flat-die production. This will generally be 500°—600°F. *melt* temperature. A single polishing take-off or casting roll may be used with flat dies, if the contact point can be brought within a fraction of an inch of the die lips and there is provision for maintaining this as a chill roll lower than 80°F. This method, or the use of a water bath within a fraction of an inch from the die, maintaining the water below 80°F where the film enters the bath, will result in extremely high transparency. Polypropylene can be oriented uniaxially or biaxially to obtain increased tensile strengths and other significant changes in appearance and performance. Polypropylene is not easily adapted to the blown-tubular film process. However, specialized techniques may make it possible to overcome some of the present difficulties, primarily low circumferential tear resistance.

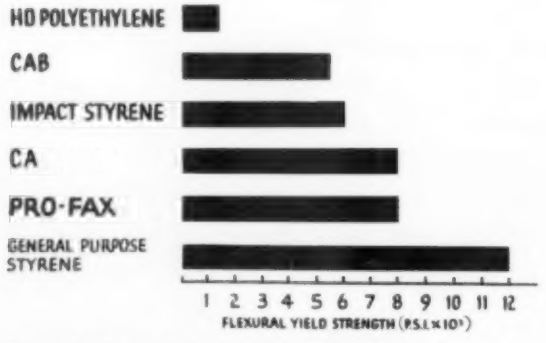

Figure 3. Flexural strength (D 790-58T).

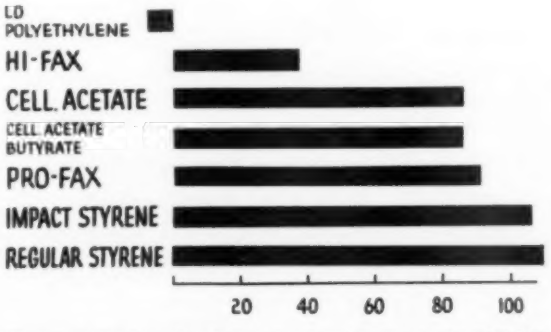

Figure 4. Surface hardness, Rockwell R Scale (D 785-51).

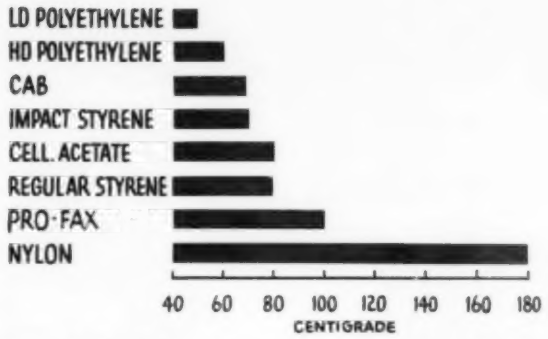

Figure 5. Heat distortion temperature at 66 psi (D 648-56T).

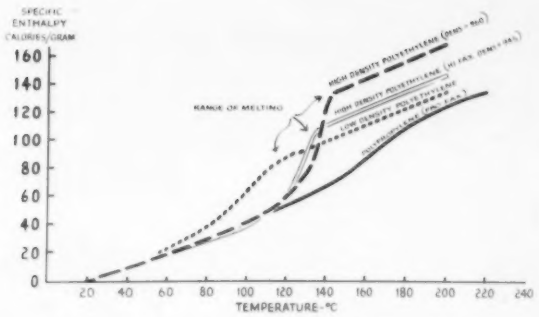

Figure 6. Specific enthalpy (heat content) of polyolefins.

Pipe, Tube and Shape Extrusion

Cylinder temperature profiles will be similar to those for sheet, i.e., progression upward to obtain a *melt* temperature of 420°—450°F. Die temperatures should be 20°—30°F lower than the hottest zone of the cylinder. Long land dies are preferred, at least 20 to 30 times the shape or tube wall thickness. Tube and pipe can be sized by any of such standard methods as internal mandrel, outside rings, or sleeves. Heavy extrusion sections, such as rod stock, must be cooled very slowly by means of high temperature baths, to prevent formation of vacuum bubbles by hardening an outer shell while the center section remains molten and subsequently shrinks away from the center on cooling. Shapes should be formed and supported by discriminate adjustment of cooled tools and/or air streams before introduction into water. It is sometimes advantageous to use heating rods to help shape complex profiles. Sizing dies or mandrels used for polyethylene will generally give larger dimensions in Pro-fax, due to its lower shrinkage. Cooling procedures in existing setups may generally be adapted to polypropylene.

As an aid in engineering a satisfactory cooling system, consideration should be given to the specific enthalpy or heat content of polypropylene. The calories of heat which must be removed per gram of material in transition from the molten, amorphous state to the crystalline polymer may be estimated from the differences in heat content at specific temperatures, (Fig. 6). For example, 110 calories must be dissipated to cool one gram of polypropylene from a likely stock temperature of 450°F to a temperature of 180°F. This graph also indicates the heating capacity necessary in plastifying polypropylene. The slope at the various points along such a curve indicates specific heat, with the steeply rising section being the range of melting and including the heat of fusion. Specific enthalpy of other polyolefins is shown in Fig. 6 for comparison.

Wire and Cable Coating

Tapered land dies are recommended, with land length to coating thickness ratio of 15 to 1 up to 50 to 1 for the thicker coatings. Drawdown of the coating from the die should not be greater than 10% to obtain the desired size. Preheating of the wire aids in rate and direction of cooling to prevent voids and loose coatings on all wire sizes over No. 18. *Melt* temperatures of 500°—600°F will be required. Gradient cooling of the coating is preferred, and may be obtained by running through two or three water baths of successively lower temperatures. Such cooling tends to increase the elongation, tensile strength, and tightness of the coating.

Miscellaneous Extrusions

Established procedures for other types of extrusion, such as paper coating, filaments, and blow molding, are generally applicable to polypropylene, provided somewhat higher temperatures are available than are used with low-density polyethylene.

SUMMARY

Extrusion application and techniques presently in commercial production indicate that polypropylene is easily adapted to most processes. Stock temperatures in the range of 400°—500°F are required for heavy sections and sheets, and somewhat higher than this as the thickness decreases.

Report on Eighth International Meeting of ISO Technical Committee on Plastics Available Free to SPE Members

An annual report of ISO/TC-61 Committee on Plastics for 1958, is being offered free of charge to all interested SPE members. Larger quantities can be obtained for a small nominal charge. SPE is pleased to extend this service in order that members may receive a comprehensive report of this important meeting held in Washington, D. C. November 3-8, 1958.

This 68-page document contains information on all activities and events which took place during the meeting, as well as details on international plastics developments and progress in the establishment of plastics standards.

It carries the minutes of the eight ISO/TC-61 Working Groups and the first draft on five ISO Recommendations.

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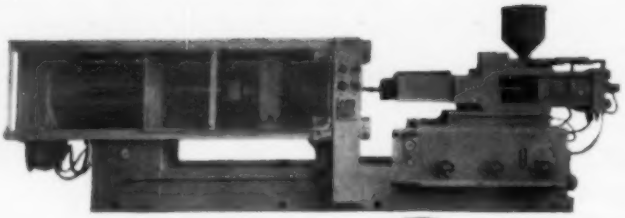
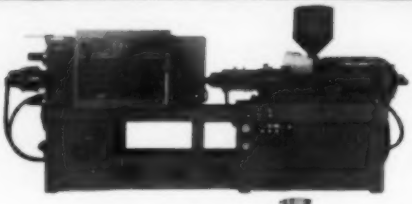


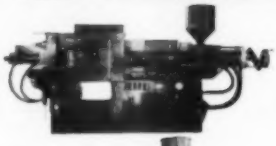
HA 28-600
28-32 Ounces
100 Ounces with
Preplasticizer



HA 16-425
16-20 Ounces

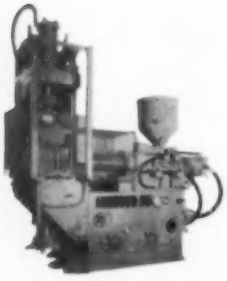
HA 12-300
12-16 Ounces

HA 8-275
8-10 Ounces



HA 4-175
4-6 Ounces

HA 2-125
2-3 Ounces



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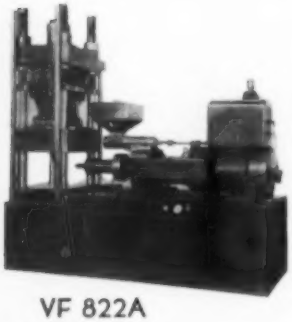
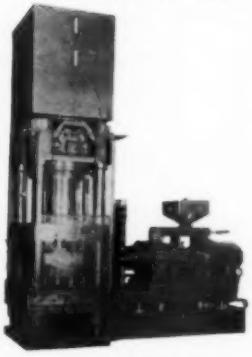
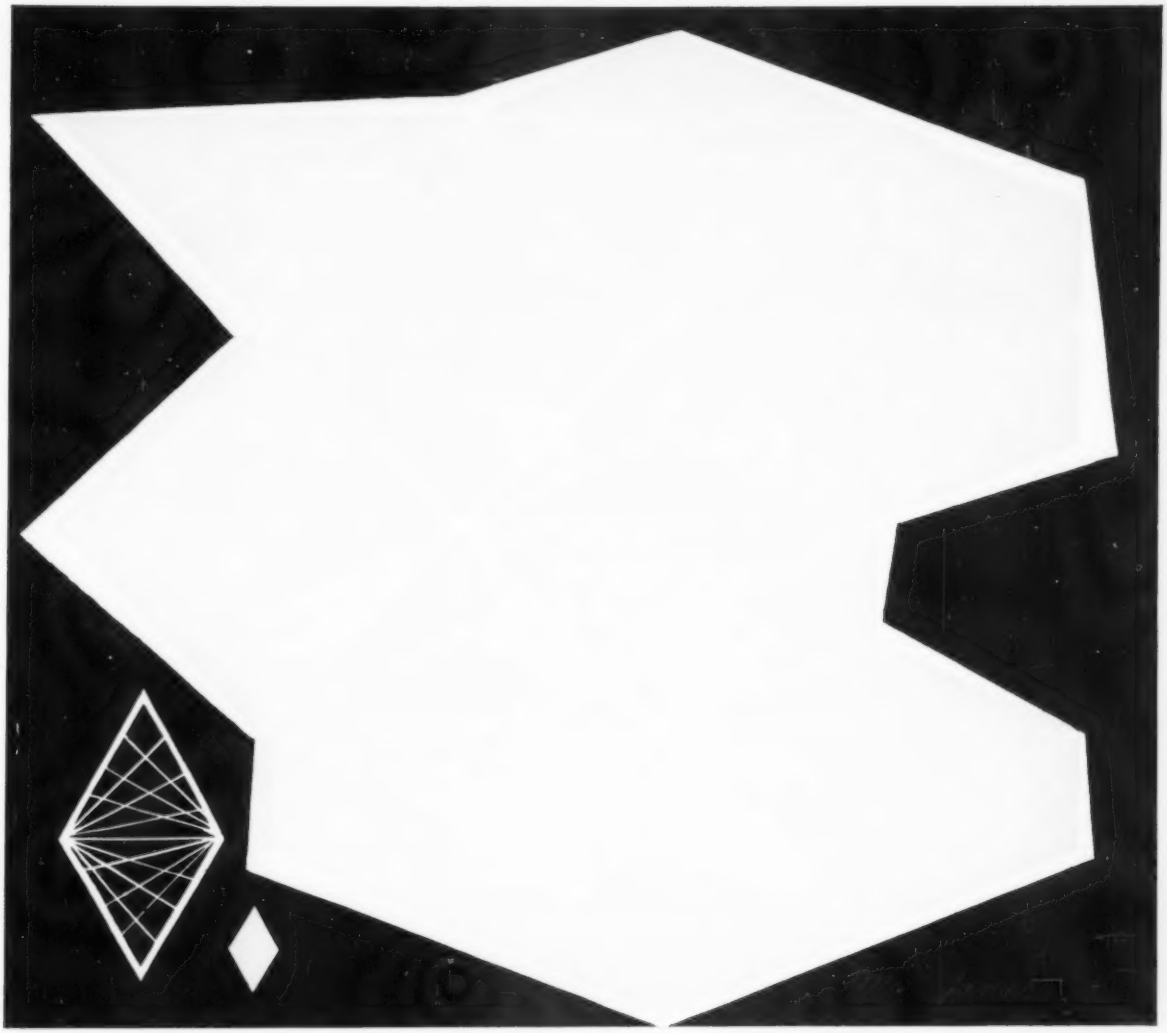


VF 822A
16-22 Ounces
80 Ounces with
Preplasticizer



VF 800
32-48 Ounces



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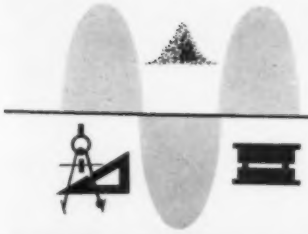


Edited by **Louis Paggi,** *Consultant*
E. I. du Pont de Nemours & Co., Inc.

FOR AUTHORITATIVE ANSWERS send your questions on molding to Louis Paggi, Sales Service Laboratory, Polychemicals Dept., E. I. du Pont de Nemours & Co., Inc., Wilmington 98, Delaware.

MOLDING CYCLES

Answers to Your Molding Problems:

- *How can you eliminate dust accumulation on moldings during shop handling?*
- *What size gate should be used to mold thick sections?*
- *Can you eject a helical gear without a rotating cavity?*

Q—We have a problem of dust accumulation on molded parts in a shop handling thermosetting as well as thermoplastic material. What can be done to eliminate or retard the accumulation of dust?

A—The best solution to the problem may be to reduce or eliminate all factors contributing to the problem. The following may serve as a guide:

1. Provide an enclosure around three sides of each compression press.
2. Attach an exhaust vent to the rear panel of each enclosure.
3. If the ceiling consists of exposed rafters and/or boards, cover with non-flaking material.
4. Paint walls and ceiling with non-chalking and non-flaking paint.
5. Maintain an atmosphere of at least 50% relative humidity in the work room. This is necessary to reduce the electrostatic charges on parts during cold weather. The relatively high humidity, while reducing the dust problem, can aggravate molding problems with materials requiring drying.
6. If the floors are of concrete, use sweeping compounds containing small quantities of oil. Avoid using heavy coatings of oil to reduce the hazard of slipping.
7. Circulate the air from the work area through a water spray or feed the incoming air through a scrubber. Static precipitators, while more expensive, are excellent for this purpose.
8. Cover all tote boxes with a sheet of plastic film.
9. Avoid excessive use of air to clean molds and general work area.
10. Avoid storage of cartons in work area.
11. Avoid regrind material in the molding room.
12. Do not open windows to outdoors to provide ventilation.

The foregoing may not necessarily cover all the possible causes of dust but may help to uncover others.

Q—We often injection mold thick sections of acrylic. There seems to be a prevalent opinion that the thickness of the gate should be 75 to 90% of the thickest portion of the cavity. Does this ratio hold when the gate would be larger than the runner feeding it?

A—Turbulent flow in the region of the gate during filling of thick cross section parts of acrylic, generally results in the formation of surface flow marks. Because of this tendency, it occasionally becomes necessary to use gates as large as the full cross-section of the part. Since such a gate will not solidify before the material in the cavity, it becomes necessary to hold the injection plunger forward until the material in the cavity solidifies. Parts produced under these conditions are highly stressed leading to the possibility of latent stress-cracking, poor solvent resistance and possibly deforming.

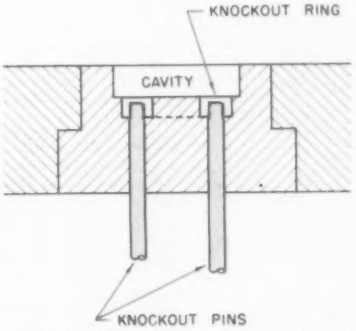
Use of a tab gate will provide a large entry into the cavity while at the same time provide for early freeze-off at the restriction.

Very large runners are not necessary because, as the relatively large volume in the cavity cools and contracts, the material from the runner flows in to make up for the loss in volume. This prolonged motion of material in the runner prevents early freeze-off of the somewhat smaller cross-section.

See "Molding Articles With Thick Sections," SPE Journal, December, 1958.

Q—Is is possible to mold a helical gear without using a rotating cavity to eject?

A—Rotating cavities in addition to being more costly, are unsatisfactory for very close concentricity work such as is usually specified for gears. Helix angles of 45° have been successfully ejected from rigidly mounted cavities. Small diameter helical gears can be ejected by a pin or sleeve positioned under the hub. Large diameter gears may require a knockout which consists of a metal ring flush mounted with the bottom of the cavity and actuated by threaded knockout pins as shown in the sketch.



For best results, the gear should be gated near the hub using three plate mold construction.

Encapsulation with putty-type Alkyd satisfies need for reliability by resistor maker and customers.

Today's creative engineers design with PLASKON Alkyd in mind for the manufacture of delicate electronic components. Here are reasons why electronic engineers prefer PLASKON putty-type Alkyds as *the* encapsulation medium:

- Simple to fabricate . . . molds quickly at extremely low pressures . . . permits rapid production cycles.
- Clean to handle . . . nothing to mix.
- Dimensional stability prevents distortion or damage to delicate inserts.
- Coefficient of linear thermal expansion is similar to that of popular wire alloys . . . reduces strain in service . . . aids the functioning of encapsulated units.
- Thermal conductivity helps to dissipate heat faster, resulting in less change in resistance value before and after encapsulation.
- Available in colors, for coding.
- More economical than most encapsulating processes.

Ultronix, Inc., San Mateo, Calif. manufacturer of quality electronic components, effectively utilizes PLASKON putty-type Alkyd in resistor production. The resistor pictured above in several stages of assembly includes an ingenious combination of three Alkyd parts—each one molded within the other—a most severe test of dimensional stability, moisture resistance, and consistency in performance. This resistor is built to meet or exceed all requirements of MIL-R-93B and MIL-R-9444.

PLASKON Alkyd Molding Compounds are outstanding for the qualities most necessary in molded parts for electronic and electrical applications. Competent Plaskon representatives will be glad to discuss material recommendations and fabricating techniques to fit your performance requirements. Telephone your local Plaskon representative or write to:

PLASTICS AND COAL CHEMICALS DIVISION
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Allied Chemical

Edited by **Thomas A. Bissell**
SPE Executive Secretary

NATIONAL ACTION

Progress Through PAG

Frank W. Reynolds

SPE National Secretary
and Administrator,
Professional Activities Groups

IF I WERE ASKED the question: "What are the greatest motivating forces for continuous growth within the SPE", my answer would be first, the individual member and second, the collective membership of the Professional Activities Groups. It is these two sources within SPE that can contribute the most to the engineering and scientific fields within the plastics industry under the banner of SPE.

What is the PAG? How and why did it originate? In 1945, the National Council approved as part of our Constitution the organization of Professsional Activities Groups "composed of members interested in particular phases of plastics engineering or science". It was established for the express purpose of furthering the progress, development and enhancement of the Society and industry.

It was not until January, 1957, twelve years later, that National Council authorized the organization of eleven professional activity groups. To date, four more have been added to this list (for a list of these groups see the March 1959, issue of the *SPE Journal*) making a total of fifteen organized engineering and scientific groups composed of members who are the recognized and unqualified authorities in their specific fields and who are associated with the multiple facets of plastics engineering.

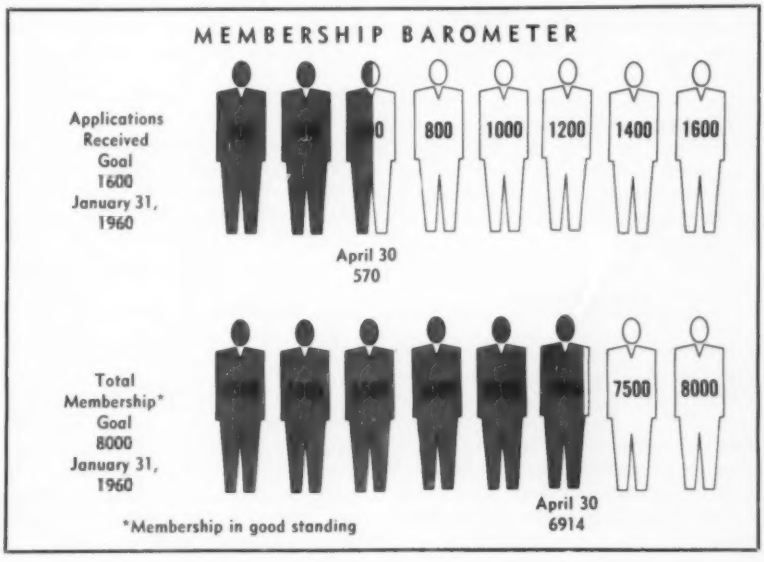
You have heard the biblical reference "A prophet is not without honor save in his own country and in his own house," to paraphrase, "the experts belong to some other organization." Applicable to this reference is the belated recognition by our Society of the tremendous contributions that the PAGs can make toward the improvement of our technical stature. Results of this growth are a clearer recognition and greater respect by the engineering profession for the authoritative position that the Society of Plastics Engineers should hold.

As evidence of this recognition, let's examine the records for some of the scheduled technical meetings, exclusive of the Sections' monthly meetings, through 1959, either sponsored by or in cooperation with the various PAGs.

On April 1 and 2, an Educational Workshop (a new form of SPE activity) sponsored by the Extrusion PAG was held at Lowell Technical Institute in Lowell, Massachusetts, under the auspices of the Eastern New England Section. The complete plan and curriculum were drawn up by the Extrusion group. There were approximately 70 extrusion specialists in attendance and the meeting was so enthusiastically received that a two-day Workshop is being held on June 16 and 17 at the Newark College of Engineering and sponsored by the Newark Section. This group is also tentatively planning to hold similar meetings in other section locations in the fall. Ironically, attendance at these Workshops must be limited, consistent with effective presentation and informal discussions.

A RETEC Symposium (Regional Technical Conference) on "Encapsulation, Printed Circuits and Fluidized-Bed Process" was sponsored by the Northern Indiana Section in cooperation with the PAG, Plastics in Electrical Insulation, at Fort Wayne, Indiana. This PAG is contributing substantially to the program.

The Finishing PAG expects to have complete plans finalized by June 1 for the RETEC, Plastics Finishing, to be held in Niagara Falls on October 16, co-sponsored by the Buffalo Section, still another contribution by PAG to the technical advancement of the Society.



Perhaps the most concrete evidence of the important part that PAG can contribute to the performance and the up-grading of our technical ventures is the fact that the General Chairman of the 16th Annual Technical Conference, to be held in Chicago, January, 1960, has stated that for the first time several symposia based on the interests of the PAG will be included in the Conference. It is also planned to reduce the number of papers to be presented from over 100 to 75 and to terminate sessions at 3:30 p.m. to permit the PAG Committees to schedule their business meetings without conflicting with the presentation of the conference papers. It is also significant to note that several PAGs are contributing papers to the technical program of this ANTEC, and that the theme of the conference will be:

Professional Achievements
and
Approaching Opportunities
in the
Growth of Plastics Engineering

The future growth of the SPE can only result from the composite interests, efforts, and contributions of each of its members toward the up-grading of our technical achievements. The best implementation for this goal is in becoming an active member of the PAG of your choice.

Let's all join PABD: "Progress Attained By Doing." Any SPE member who wishes to join a PAG can do so by writing to its chairman listed on pages 245 and 246, March, 1959 issue, SPE Journal.

spe

TECHNICAL MEETINGS CALENDAR

16TH ANTEC

ANNUAL TECHNICAL CONFERENCE—January 12-15, 1960, The Conrad Hilton, Chicago, Ill. Sponsored by the Chicago Section. For more information, contact General Chairman Franklin L. Fine, Rohm & Haas Co., 5750 W. Jarvis Ave., Chicago 31, Ill. Request for papers on page 275 of the April SPE Journal.

1959 NATEC

NATIONAL TECHNICAL CONFERENCE—October 13-14, 1959. The Ambassador, Los Angeles, Calif. For more information, contact General Chairman, Jack G. Fuller, c/o Chemtrol Co. 10872 Stanford Ave., Lynwood, Calif. See tentative program on page 273 of the April SPE Journal.

WORKSHOP

EXTRUSION—June 16 and 17, 1959, Newark College of Engineering, Newark, N. J. Sponsored by Newark Section in cooperation with the Extrusion PAG. Registration is limited to members of the Newark and New York Sections. For more details see page 435 of the May issue.

RETECS

PLASTICS IN THE AUTOMOTIVE INDUSTRY—June 30, 1959. Sponsored by the Detroit Section in cooperation with the Plastics in the Automotive Industry PAG. For information write to Co-Chairman John Donalds, The Dow Chemical Co., 450 Fisher Bldg., Detroit 2, Mich. For complete program see page 443 of the May issue.

VINYL PLASTICS—October 7, 1959, Cleveland, Ohio. Sponsored by the Cleveland Section. For information write to William Messina, 414 Shawnee Place, Huron, Ohio.

PLASTICS FINISHING—October 16, 1959, The Niagara Hotel, Niagara Falls, N. Y. Sponsored by the Buffalo Section in cooperation with the Plastics Finishing PAG. For information write to Chairman Gordon K. Storin, 3 Forest Rd., Lewiston Heights, Lewiston, N. Y.

PLASTICS IN THE SHOE INDUSTRY—November 4, 1959, St. Louis, Mo. Sponsored by the St. Louis Section. For more information write to Otto Wulfert, Chairman, c/o Wagner Electric Co., 6400 Plymouth Ave., St. Louis 14, Mo.

PLASTICS IN PACKAGING—November 19, 1959, San Francisco, Calif. Sponsored by the Golden Gate Section. For information write to Chairman Frank D. Allen, L. H. Butcher Co., 15th & Vermont Sts., San Francisco 1, Calif.

STABILITY OF PLASTICS—December 1959, Washington, D. C. Sponsored by the Baltimore-Washington Section. For information write to Chairman Myron G. DeFries, Atlantic Research Corp., Alexandria, Va.

SECTION MEETINGS

MIAMI VALLEY—June 12, 1959. Annual Picnic at the Elk's Country Club, outside Hamilton, Ohio, on Route 4.

PHILADELPHIA—June 17, 1959, Newark Country Club. Annual Golf Outing sponsored by the Philadelphia Section. The Continental Diamond Fibre Co., Newark, Delaware are hosts. For information contact George H. Koch, Jr., 110 Monmouth St., Gloucester City, N. J.

GOLDEN GATE—June 25, 1959. A tour of the Hiller Aircraft plant will be featured. Dinner location to be announced.

SECTION NEWS

Eastern New England

First Vinyl Sub Section Meets. General Group Hears J. Harry DuBois

H. C Cookingham

On March 24th the monthly meeting was held at Armand's Beacon Terrace, Framingham, Mass., with 168 members and guests in attendance.

This is the first meeting that has been held since the organization of the Vinyl Sub-Section of the Eastern New England Section. The Vinyl Sub-Section has as its chairman, Jack Parker, Abby Plastics Co., Hudson, Mass. Chairman of the Vinyl Sub-Section Program Committee is George Fountas, Chemical Products Corp., East Providence, R.I.

George Kovach, President, presided during the dinner, and introduced the guests present. After dinner, the general group and the Vinyl group separated and held individual meetings.

The speaker at the general group was J. Harry DuBois, who spoke on "New Piastic Materials and Their Applications."

The Vinyl Sub-group was under the general chairmanship of Jack Parker, Chairman ot the Vinyl Group, and a group of speakers were presented. Ivan Mankowich, Naugatuck Chemical Co., spoke on "Family of Vinyl Resins:" G. Cohan, Goodrich Chemical Co., discussed, "Resins for Extrusion Molding:" A.E. Whitney, Goodyear Chemical Co., "Resin Coatings;" T.J. Haselton, Monsanto Chemical Co., "Resins for Calendering," and F. W. Wurtzell, Union Carbide Plastics Co., spoke on "Past and Future Trends in the Vinyl Industry."

The April meeting was held at the Maridor Restaurant, Framingham, Mass, with 68 members and guests in attendance.

George Kovach, President, presided during dinner, and introduced the speakers of the evening.

Frank G. Rice, Plastics Division of DuPont of Canada, Ltd., was guest speaker at the General session. His subject was "The Canadian Booby Trap," a discussion of the problems involved when companies in the U.S. become active in Canada.

Felix Schirato, Pluess Stauffer Co., and Emil W. Schwartz, Southern Clays, Inc., were guest speakers at the Vinyl Sub-Group Session. Mr. Schirato spoke about the use of calcium carbonate fillers in polyvinyl chlorides, and Mr. Schwartz discussed the use of clay fillers.

Milwaukee

Portrait in Plastics

James C. Engman

During the April meeting, attended by forty members, Paul Wright, Eastman Chemical Co., presented the first local showing of a film "Portrait in Plastics."

Section Past President Charles Egan, Owens-Corning Fiberglas attended his last meeting prior to relocating in Toledo. The members wished him well and acknowledged his Society efforts with gratitude.

Miami Valley

Linear Polyethylene and Phenolics

Stephen D. Marcey

On May 7th the meeting was held at the Golden Lamb Hotel in Lebanon, Ohio. A dual presentation was on the agenda consisting of talks by M.W. Davidson, Phillips Chemical Co., and R.W. Bice, The Formica Co.

Mr. Davidson presented a technical discussion on the properties and applications of high density polyethylene. This was followed by a summary of production problems involved with the molding of phenolic materials in specific applications as presented by R.W. Bice.

Members were told of the annual picnic to be held on June 12th at the Elk's Country Club, Rt. 4, outside of Hamilton, Ohio.

Chicago

Mr. Sutro, SPE National President, is Guest

Harry E. Bennett

Frederick C. Sutro, Jr., SPE National President, Spencer Chemical Co., was guest at dinner of the April meeting. Mr. Sutro spoke of the need for further activity in the PAG at the local level, not only as a means to increase interest and attendance at local monthly meetings but also as a basis and foundation for future growth and increased stature for our Society. Mr. Sutro stated that the adoption of a Newsletter by local SPE Sections has proved to be an outstanding means of promoting member interest in local activities and in getting important messages across to the membership. Present plans in Chicago definitely include action on both these vital subjects.

Pittsburgh

Plastics in the Electrical Field

John E. Parks

Two guest speakers were heard during the March meeting, which was held at the Sherwyn Hotel.

Joseph Groel, Bakelite Co., emphasized in his talk the tremendous expansion in the thermoplastics materials being used in the electrical field. He gave a comprehensive report on the extrusion of vinyls and polyethylenes.

W. C. Wickstrand, American Cyanamid Co., pinpointed his talk on the thermosetting materials, and illustrated by charts the physical and dielectric properties of the thermoset plastics. Mr. Wickstrand also discussed the testing methods of thermoset materials in the electrical industry.

Headtable notables at the North Texas Section RETEC, left to right, seated: E. H. Swazey, Section President; Jules W. Lindau III, National 2nd Vice President; T. T. Tucker, Jr., President Elect of the North Texas Section; Thomas A. Bissell, Executive Secretary of the National SPE; and Richard Jenkins, National Director from the North Texas Section. Standing, left to right; Hubert Poskey, Section Treasurer; David A. Daniels, Secretary; J. E. FitzGerald, main speaker at the luncheon; and William McConnell, RETEC Chairman.

North Texas

North Texas Section Holds First RETEC

Robert Craft

The major technical phase of plastics manufacturing in the North Texas area received enthusiastic response in Dallas on April 28, when the North Texas Section first RETEC was attended by 275 members and guests.

William McConnell, RETEC Chairman, vice president of Air Accessories, headed a committee of more than 40 NTS-SPE members, who spent several months preparing for their first RETEC.

Program Chairmen were: Dominic Novelli, Convair, Aircraft Chairman, and Ben Whitehouse, Whitehouse Plastics, Boat Chairman; Registration Chairman, Ray Uber, Phillips Chemical Co.; Treasurer, Clarence Garrard, Fort Worth National Bank; Publicity, T.T. Tucker, Jr., Tommy Tucker Plastics; Printing, John Gillette, Air Accessories. Committee Advisors; E. H. Swazey, Section President, vice president and chief engineer, Lone Star Plastics; Richard Jenkins, National Director, Coast Mfg. & Supply; Raymond Perkins, Southwestern Plastic Pipe; Alvis Barrier, The Barrier Corp.

A highlight of the meeting was the luncheon speech by J. E. FitzGerald, Brunswicke-Balke-Collender Co., who recently returned from a tour of Russia and showed a series of colored slides of his trip.

Western New England

Spot-A-Mation

Armand G. Winfield

Hales S. Cadieux, N. Y. district manager of The Bellows Co., gave an illustrated talk and a 30-minute film called "Operation Push Button."

Basically, Mr. Cadieux attempted to clarify automation and to then demonstrate a variety of uses of controlled air power in factory operations.

Most persons have confused interpretations of automation. Most think it is similar to a system where molten metal goes into a production line at one end of a plant—and a finished packaged metal part is delivered at the opposite end of the line without the aid of human hands. This is true in isolated cases, but most automation, or what could be more precisely defined as "Spot-A-Mation" is concerned with one, two or even possibly three operations.

Automation is money-saving: (a) Automation is responsible for the production of more pieces per labor dollar. (b) Automation cuts down scrap. (c) Automation increases the life of the tools thus giving greater efficiency to tools and cuts amortization cost of the tool. (d) Automation provides for more constantly accurate and precise workmanship, when the human element is removed, when operator fatigue becomes nonexistent. When all chance and variation is taken away, the parts become uniform, quality parts.

Automation is concerned with the same operations which are done by hand on metal, wood and plastics. The film, "Operation Push Button," was a dramatic and vividly visual demonstration of accurate time-saving devices used in manufacturing operations.

Pneumatic controls are faster than hydraulics and more flexible than gears or cams. Coupled with micro switches, timers and other such devices, the controlled air cylinder becomes the key tool in this age of industrial technology.

Ever since man has learned to roll a stone rather than carry it, he has tried to find ways of making necessary operations easy for himself. This is the basis for automation. In industrial prominence since the boom of World War II, the versatile time-savers are now used in every industry.

Kentuckiana

Request PAG Interest

R. O. Carhart

Section President Roy Eshenaur asked that anyone interested in the various PAG's make their interest known to him in order to get representation on more groups than at present. During this April meeting, John Berutich then gave a brief summary of the second regular meeting of the National Council.

Guest speakers were introduced by Program Chairman, John Schmitz. Watson Warriner and Norman James, both of DuPont, rendered informative talks concerning the product Delrin.

Bartlesville-Tulsa

Polystyrene & Polyethylene Melt Flow

Ron Marsh

Following the social hour and dinner of the March meeting, Section President J.N. Scott called the meeting to order and asked that member Tony Bottomley lead the group in invocation. President Scott informed those in attendance that the Board of Directors had unanimously consented to discontinue monthly meetings during the months of June, July and August.

Program Chairman Robert Doyle introduced Walter S. Kaghan, Chief, Development Section, Olin Mathieson Chemical Corp. Mr. Kaghan proceeded to talk on "The Melt Flow of Polystyrene and Polyethylene." He also showed several high-speed motion pictures on the effect of various shear stresses encountered during extrusion of these polymers. He explained how these factors were quantitatively correlated to determine the optimum die design to prevent melt fracture of the resins. Prior to the Section Meeting, the Board of Directors met and discussion was held regarding subjects which should be transmitted to the National Office to aid in the preparation of a procedure manual. The following points were to be included in a letter to the National Office: (1) More specific instructions on membership prior to receipt of National Charter by a new Section. (2) The need for a National Councilman to be present at the initial Steering Committee meeting for the formation of a new Section. (3) More definite rulings as to whether or not the Section Officers should be selected from the Board of Directors.

Connecticut

Polishing and Plating

K. G. Clarke

"Polishing and Plating of Molds and Molding and Extrusion Equipment" was the topic for discussion at the monthly meeting of the Connecticut Section held on April 10th at the Hotel Barnum in Bridgeport. Ronald T. Delaney of Mirror Polishing & Plating Co., Inc., was the guest speaker of the evening.

A good chromium plater will be able to offer finishes of many types: 1. Bright range, (mirror finish); 2. Satin finish; 3. Matte finish; 4. Grained finish; 5. Open grain finish.

Mr. Delaney also discussed the specific problems involved with coatings of various thickness, types of metals which can be plated, optical surfaces and wear-resistant surfaces.

Connecticut

Plastics in Building

K. G. Clarke

Dr. Fred McGarry, Assistant Professor at Massachusetts Institute of Technology, was the guest speaker at the May meeting held at the Hotel Barnum in Bridgeport, Conn. He presented facts and figures which pointed up the challenge to the plastics industry presented by this giant market for materials.

Dr. McGarry stated that the major roadblocks to more extensive use of plastics in building are: high cost, low strength and stiffness, lack of design data, poor reputation with consumers, and conservative building codes.

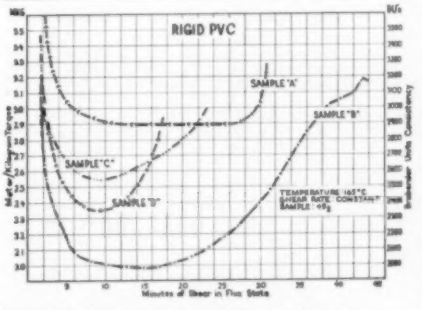
The best possibilities for plastics lie in the field of additional equipment in homes, such as appliances, gadgets, etc., which according to present trends are increasing at a much faster rate than the homes themselves.

Central New York

Mold Designing

James R. Lampman

After a brief business meeting conducted by President Norman Berg, the program for the April meeting was turned over to John Andros, chief engineer of the Major Mold and Die Co., East Detroit, Michigan. Mr. Andros described some of the problems encountered in designing large molds. The word pictures he painted concerning the operation of building these large molds from blocks of steel were extremely interesting and informative. He offered several tips on mold making and the use of models for Keller tools and pointed out the economic necessities for utilizing inserts in certain design areas.



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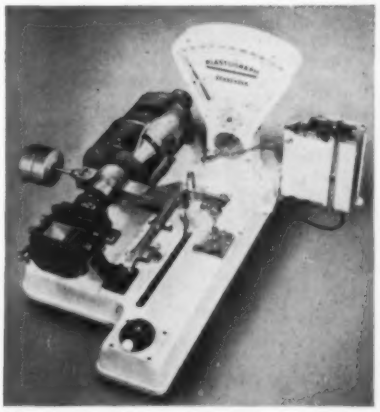

New York

Polypropylene and Epoxy Plasticizers for Vinyl Compounds

Charles C. Orr

More than 200 members and guests gathered April 15 at the Governor Clinton Hotel to attend the regular monthly meeting.

A paper entitled, "Polypropylene, Methods of Fabrication, and Applications," was delivered by John Y. Lomax, Hercules Powder Co. Mr. Lomax discussed the unique properties of this olefin polymer, as well as its mechanical behavior in about 20 molded and extruded items. The discussion was supplemented with slides which compared the physical properties of polypropylene with other resins.

VIPAC was host to two speakers on epoxy plasticizers for vinyl compounds. This program was moderated by Irwin L. Podell, Irwin L. Podell, Inc., who outlined their purpose and use. These plasticizers fall into two types: soy bean epoxy, and ester-type epoxy.

R.F. Coyne, Rohm & Haas Co. talked on "Plasticization of Polyvinyl Chloride with Oil Epoxides." Oil epoxide plasticizers contribute simultaneously to both plasticization and stabilization of PVC compounds, although their contribution effects on light stability are less predictable. Oil epoxides enhance the durability of vinyls because of their resistance to volatility and extraction loss. Certain conditions cause a loss of compatability with PVC compounds, but this pitfall can be avoided by careful formulation.

"Monomeric Epoxy Plasticizers-Their Contribution to the Vinyl Compound," was discussed by Joseph Fath, Thompson Chemical Co. Use of these materials is expected to grow rapidly due to a better definition of their place in vinyl compounds. At present, four epoxy fatty acid esters dominate the commercial market. Their performance properties were compared to provide a clearer understanding of the place for each. In estimating the quality of an epoxy plasticizer, undue stress has been placed on residual iodine number. It is suggested that oxirane efficiency be considered in combination with residual unsaturation. New evidence shows that monomeric epoxies are more compatible than had been assumed previously. Further, they show excellent low temperature performance, and yield low viscosity plastisols. In view of this, their re-examination for present and future applications is proposed.

St. Louis

Polycarbonate Resins

Lyle R. Dean

W. F. Christopher, manager of polycarbonate market development, chemical materials dept., General Electric Co., was speaker at the April meeting.

Mr. Christopher described GE's new thermoplastic molding compound Lexan polycarbonate resin. He had an interesting array of samples to assist in describing some of the outstanding properties of this material, such as, its transparency, its excellent resistance to creep and cold flow, its high heat distortion temperature, its extremely high impact strength, its good electrical properties, and dimensional stability.

Mr. Christopher also mentioned some of its limitations, such as, poor solvent resistance to many solvents, limited abrasion resistance such as would be required for gears and bearings, and its need for extremely low moisture content during processing.

Mr. Christopher also described several commercial applications in which this product has been found to be the only thermoplastic that was suitable. Some of the more interesting of these were electrical connectors used as current carrying members.

Southern

Tour and Film

James W. Root

A tour through the Atlanta plants of the Carling Brewing Co., and Gordon Foods, Inc., was made during the April meeting.

At the May dinner meeting, Ray Kruse, Rohm & Haas Co., spoke on the testing of plastic materials and was followed by the showing of a film "Futures Unlimited." This film, produced by Zenith Plastics Division, described the manufacture of polyester radomes.

Cleveland

Three Star Special Program is Held

R. L. Huber

A Three Star Special Program was held on April 20th, at the Scientific Center of the Cleveland Engineering Society, as a panel discussion to review the polyolefins. The discussion was presented in four parts: low density, medium density, high density polyethylene, and polypropylene. Fabrications and applications of these outstanding materials were carefully reviewed.

The Three Stars, our panel members, represented the finest professional caliber our Society can present, and are: Frederick C. Sutro, Jr., SPE National President and product manager of the Plastic Div., Spencer Chemical Co.; W. O. Bracken, SPE National Past President, sales development, Hercules Powder Co.; W. P. Gideon, manager sales division, Eastern Chemical Co. The distinguished speaking group on polyolefins followed official greetings on a SPE National level by our National President.

Mr. Gideon presented an optimistic picture of low density for closures and blow molding. Films are one of the stronger segments of low density polyethylene's market and include overwrap and fruit packaging. This is stressed as a very strong market for low density polyethylene.

Mr. Sutro said that medium density is now produced by three methods: high pressure, low pressure, and blending the two. Economic position is a strong point of medium density polyethylene. Clarity is generally maximum in the medium density range. Overwrap is strongly moving into the cellophane market for bread, napkins, etc. Estimate of 60,000,000 pound market in bread alone.

Mr. Bracken reviewed in detail the promising growth possibilities of high density and pointed emphatically to blown bottles and pipe. He discussed carefully the different types and performance factors within the high density group.

Large numbers of use items of polypropylene were exhibited and the basic properties reviewed. Fibers, films and multi-sized moldings prompted a lively question period.

Southeast New England

Molding Techniques in the Automotive Industry

Ray R. Bottleman

Eugene Quear, Supervisor of Plastics Engineering at Delco-Remy Div., General Motors Corp., was guest speaker at the March meeting. Mr. Quear's subject was "Molding Techniques That Pay Off in the Automotive Industry." Slides were shown to illustrate the many processes.

Delco-Remy handles injection, compression, high-speed plunger molding and extruding. The company is a pioneer in automatic injection molding, having run molds automatically since 1938.

In the compression molding department, Delco-Remy has built many of its own machines since no standard machines are available for the special jobs required. One such machine is a high-speed plunger molding press used specifically for molding around inserts. The press has one top mold half which engages one of two bottom mold halves operating on an indexing arrangement. While one bottom mold is in molding position, the other is loaded with inserts.

Mr. Quear discussed another high speed plunger molding machine built to work fully automatically. The press operates in similar fashion on to a horizontal injection molding machine. Preforms are electronically heated to 365°F and then conveyed to a mold at 410°F. These temperatures together with a high speed plunger make possible cure times of 6 to 8 seconds.

Northwestern Pennsylvania

Use of Adhesives

John J. August

Guest speaker at the April meeting, held in the Eagles Club, Erie, Pa., was Paul C. Strane, Minnesota Mining and Mfg. Co., Cleveland, Ohio, who spoke on "Adhesives" for present and future use in home and industry. A discussion period followed on metal-to-metal bonding.

The meeting was attended by thirty-five members and guests.

Southeastern Ohio

Induction Heating

William J. Stranathan

The April meeting was held in the Pioneer Room of the Berwick Hotel, Cambridge, Ohio, which was attended by 32 members and guests.

E. W. Wendelken, Program Chairman, introduced the speaker of the evening, Al Hartman, Hale and Kullgren Inc., Div. Aetna Standard Engineering Co. Mr. Hartman stated that by the use of induction heating; (1) Electric energy is used much more efficiently; (2) Precision temperature control is for the first time possible without the use of complicated control systems; (3) Maintenance problems are greatly reduced due to the lower heat levels involved; (4) Better working conditions as there is much lowered temperatures at the outside of injection and extruder cylinders; (5) The operating temperatures are much lower which adds much to the life of the induction heating coils.

Mr. Hartman also mentioned that with all these advantages the one drawback is the first cost. It is three to four times the cost of present resistance units. However, when all factors are considered, including reduced maintenance, down-time and scrap production, as well as reduced operating costs, the extra expenditures will be justified.

Central Indiana

Blow Molding Aspects

Wayne Nicely

Sixty-two members and guests attended the April meeting held at the Severin Hotel in Indianapolis.

T.J. Mullen, Celanese Corporation, was guest speaker. He discussed blow molding, its uses, equipment, cost and efficiency. His speech was well illustrated with sample parts and slides.

During the meeting plans were announced for the annual outing, which will be held at the Anderson Indiana Country Club on June 6th. Plans include all day golfing, horseshoes, volley ball, lunch, and numerous door prizes as well as prizes for golf.

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Philadelphia

Extrusion Program

Ernest G. Schwab

Over 110 members and guests attended the March meeting on Extrusion given by Prodex Corp. and Frank Nissel. Discussed were techniques for valve extrusion which included information on devolitizing extrusion. Mr. Nissel discussed and emphasized the importance of good controls and high speeds. Extrusion of various materials was explained and also the need of knowing the pressure on the material internally in the cylinder. Venting of the gases inside the cylinder was also included in this talk.

Rochester

Polyolefin Properties and Blow Molding

John T. Bent

Forty-five members were present at the March meeting. Mr. Cleaver reported on the progress of arrangements for the annual cruise. The Treasurer's report was given by Mr. Erdly, who noted that the balance at present was $420.03 and that this should be adequate for financing the spring cruise.

Featured speakers were Frank Kelly and Tom Mullen from Celanese. Mr. Kelly discussed polyolefin copolymers, their properties and applications. He pointed out that the copolymer gave vastly improved stress cracking resistance, but in doing so it was necessary to make some sacrifice of the other properties of high-density polyethylene.

Mr. Mullen spoke on blow molding of polyolefins and applications and displayed samples illustrating the range of products which could be produced by the blow molding process.

At the April meeting, Dr. George Kruder, Director of Research for the Kordite Co., was introduced and addressed the sixty-five members present on "Research in the Plastics Industry at the Convertor Level." This paper discussed statistically the sources of information available to convertors in making the decision as to where their efforts should be directed. The convertors' individual efforts, Dr. Kruder pointed out, tended to be short termed and secretive in nature.

A detailed analysis in layman's terms on factors governing the decision to embark on a new venture was discussed. Costs of new ventures and the organization of the research team involved were enumerated.

Toledo

Glass Filled Thermoplastics

R. E. Dunham

Rexford Brodt, vice president, The Fiberfil Corp., Warsaw, Indiana, was the speaker at the April meeting held at the Moongate Supper Club.

Glass fiber filled thermoplastic molding compounds made by Fiberfil are bonded by special techniques with a good bond being the key to the process. Three methods can be used: latex saturation, melt saturation, and prepolymer syrup in which a chemical reaction is carried out on the fibers.

Mr. Brodt stated that polystyrene and nylon are most adaptable to be filled but polyethylene and Delrin have been t.ied with only moderate success due to poor bonding. The materials can only be injection molded.

He went on to explain that a more rigid and dimensionally stable molded part of higher strength and higher heat resistance results from filled as compared to unfilled. Stress relieving treatment isn't needed. Regrind can be reused by blending with virgin material. If 100% regrind is remolded, an increase in tensile strength over a virgin part will usually result but impact strength is lowered. Dimensional stability and heat distortion are unchanged in 100% regrind.

Binghamton

Reliability and Vendor Control

Leo J. Pranitis

On March 26th the monthly meeting was held at the Vestal Steak House. Guest speaker was John Schneider, Staff Engineer at IBM Endicott. A graduate of Syracuse University, Mr. Schneider has been with IBM since 1954. His work has been directed towards reliability of their standard modular system. A member of the IRE, AIIC, ASQC, he also authored a paper on Quality Control published by Industrial Quality Control Magazine in September, 1958.

"Reliability and Vendor Control" was his topic of discussion.

C. L. Ward

Binghamton

Reinforced Plastics

L. N. Chellis

Forty-nine members and guests were present during the April meeting, held at the Carlton Hotel.

President Leroy Chellis announced that the Board of Directors has appointed John E. Gwyn, Consolidated Molded Products Co. as National Councilman to fill out the term of Frank Reynolds who is now National Secretary and Councilman-at-Large. Mr. Gwyn is a charter member of the Binghamton Section. He has been active in the work of the local section, having served as a member of the Board of Directors, Treasurer, and Chairman of the Membership Committee for one season.

Hy Nathan, SPE National Treasurer, and President of Atlas Plastics Co., discussed "Hand Layup and Vacuum Bag Molding of Reinforced Plastics." He traced the interesting history of this type of molding and illustrated the work with samples of products made by both methods. The second speaker, C.L. Ward, vice president and general manager of Molded Fiber Glass Co., spoke on "Matched Metal Molding of Reinforced Plastics." He emphasized the necessity for good tooling and adequate press equipment for production of quality parts. Proper design of reinforced plastic parts was discussed and illustrated by means of several complex molded parts.

Central Ohio

Officer Nominations and Meeting Report

Gary C. Fulmer

During the March meeting, held at Presutti's Villa, the Secretary's and Treasurer's reports were given, and old and new business was discussed. President Robert Zimmerman asked for any further information or opinions that members wished to give him on the recent ANTEC. An outline was presented to the members showing what was required and a suggested method of procedure for holding a RETEC. All members were asked to review this and give any opinions they had regarding it.

The officers and directors presented a slate of nominations for officers for the year of 1959 and 1960. These nominations were as follows:

President— Bill Rackett; Vice President—Robert King, Gary Fulmer; Secretary—Richard Sharp, Richard Beck; Treasurer—Charles Winter, James Basford; Directors William Yost, Thomas Webster, Jr.

Baltimore-Washington

Plastics in Packaging

Taylor E. Birckhead

At the March 10th meeting, Bill Simms spoke to the SPE membership on "Plastics in Packaging." He covered the history of this form of packaging from its beginning in the 1930's to its present growth of $12 billion per year.

Approximately one out of every eight pounds of resin produced goes into this field. Of particular interest was the effect on the plastics program of the new Food & Drug Administration legislation.

Golden Gate

Announce PAG Association

Theo. V. Malianni

Sixty-one members and guests attended the April meeting, held at San Francisco's Paris Louvre.

Following dinner, President James Turner presided over a short business meeting during which he announced that this Section is now associated with the PAG and outlined the advantages that will accrue from this association. He also announced that because of the many vacations taken during July and August, the Board of Directors decided to suspend summer meetings.

After introduction of all members, guests, and one new member, Kenneth Anderson, Dow-Corning, President Turner turned the meeting over to Program Chairman William Richardson who introduced Dr. C. R. Lindegren, technical service representative for Du Pont, as the speaker of the evening.

Aided by color slides, Dr. Lindegren presented a complete and comprehensive analysis of Delrin, Du Pont's new and unique thermoplastic engineering material, acetal resin which is superpolyoxmethylene, the first commercially useful high molecular weight polymer of formaldehyde. It is a material with a combination of properties not found in any other thermoplastic.

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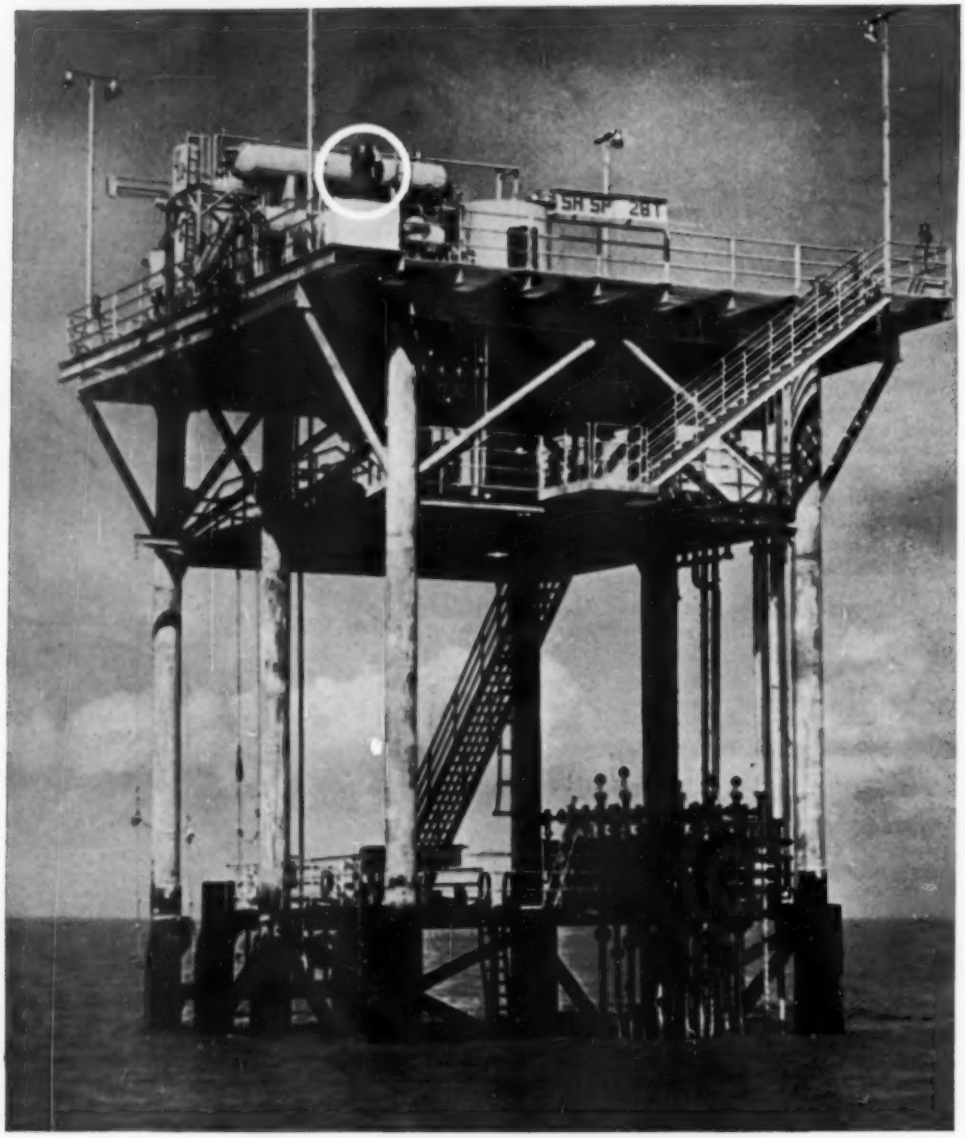

Winner of an Award of Merit for design excellence at the 14th Annual Exhibit and Conference of the Reinforced Plastics Division, The Society of the Plastics Industry, Inc.

Four ft. tall and 17⅝ in. in diameter, the horn is produced by Wallace & Tiernan Inc., Belleville, N. J.

CAREFREE SENTINEL ON THE GULF OF MEXICO

The man-made oil drilling islands at the mouth of the Mississippi are under continuous corrosive attack by harsh marine atmospheres. So equipment must be made *impervious* to corrosion. The foghorn, for instance, that warns shipping of the presence of islands, like this Shell Oil Company, Delta Division, oil-drilling rig, is fabricated of rugged glass-reinforced LAMINAC® polyester resin. The reinforced LAMINAC foghorn is completely *corrosion resistant*, as well as resistant to impact. Weighing just 120 pounds, it can be lifted by one man. The previous metal horn required a crane to move it. *And the reinforced plastic horn requires no maintenance.*

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ABOUT MEMBERS

J. Harry DuBois has purchased Tech Art Plastics Co., Morristown, N. J. Mr. DuBois of Montclair, N. J. is proprietor of his own plastics consulting firm and is a director of National Beryllia Corp. He will become chairman of the board of Tech Art. He is National Past President of SPE (1948), Newark Section, a member of the 15th ANTEC Executive Committee and the Ad Hoc Committee for Future Organization of the Management of the Society. Mr. DuBois will present a paper "The Expanding Polymer Horizon," at the forthcoming SAE meeting to be held in Atlantic City, in June.

John P. Lombardi has been appointed vice president —manufacturing of Tech Art Plastics Co. Mr. Lombardi is widely recognized as one of the most experienced plastics engineers of the industry. He started as a molder in 1934, and has worked in every phase of the business. Mr. Lombardi was associated with Shaw Insulator Co., Plax Corp., and Listento Records Inc. He has also been employed as consultant on plastics molding and production problems. A graduate of Stevens Institute, he is Chairman of the SPE Steering Committee, Newark Section and a member of the SPE Journal Editorial Advisory Board. Mr. Lombardi serves Newark College of Engineering as an instructor of Plastics Technology.

J. Harry DuBois

John P. Lombardi

Edwin E. Woodman was appointed district sales manager of the Chicago office of the Hooker Chemical Corp. Mr. Woodman joined the sales department in 1931 and has been a Durez salesman in the Chicago district for more than 20 years. He has also been in technical service and an assistant plant superintendent. Mr. Woodman studied engineering at Kansas State Teachers College, and is a member of SPE as well as a member and Past President of the Chicago Section.

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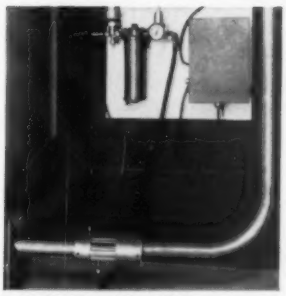

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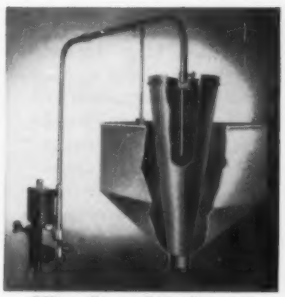

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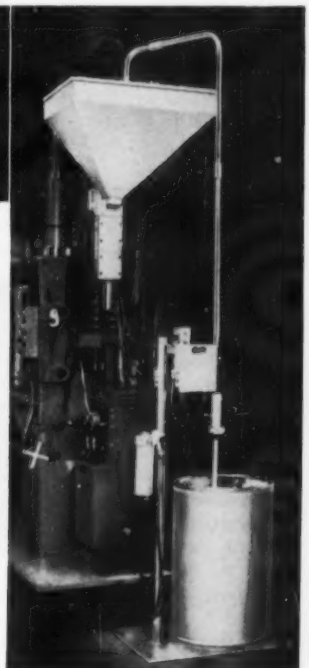

Self Supporting Conveyors

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Glenn A. Tanner, has been appointed sales manager of Auto-Blow Corp., it was announced by E. B. Stratton, general manager of the Bridgeport, Conn. firm. Mr. Tanner has held sales and engineering positions in government ordnance, with Republic Steel Co., and Sherwin Williams Co. Prior to joining Auto-Blow Corp. he was associated with Ralph B. Symons Associates, Inc. A graduate of Ohio State University, Mr. Tanner served as a USAAF pilot during World War II. He is affiliated with the Rhode Island Section of SPE.

Glenn A. Tanner

Wayne Smith

Wayne Smith has been appointed to the sales staff of Detroit Mold Engineering Co., it was announced by L. J. Morrison, vice president in charge of sales. Mr. Smith has served in various capacities as a mold buyer and mold estimator at Erie Resistor Corp., and has held similar positions at Anson Tools and Gages, Inc. in Erie. He received his BS at Pennsylvania State University. His experience in the field of mold construction will be of considerable assistance to molders in Western N. Y., Western Pa., and Ontario, Canada, where he will represent D-M-E. Mr. Smith is affiliated with the Erie Section of the SPE.

OBITUARY

John B. Hendrickson, founder of Welding Engineers, Inc. and Chairman of the Board, died May 1st at Chestnut Hill Hospital, Phila. He headed the company through many phases of growth in metalworking, shipbuilding and manufacturing of specialized plastics processing machinery. He was an inventor and holder of numerous important patents. Mr. Hendrickson resided at West Valley Green Rd., Whitemarsh. He was an alumnus of Cornell University and a member of the class of 1920. Mr. Hendrickson was a Director of Dominion Welding Engineering, Ltd., Canada. He was a member of the Pine Valley Golf Club in N. J., Cornell Club of Philadelphia, SPE Philadelphia Section, and SPI.

Narvelle Arant, died on April 19th in Mexico City while on his honeymoon. Mr. Arant, who was 45 years of age, was an associate of Arant & Co., and an active member of the Golden Gate Section. He was an expert on vacuum drawing and injection molding, being one of the original developers of the space helmet.

Classified Ads

POSITIONS WANTED

Production Supervisor

Seven years experience in vinyls, both virgin and reprocessed, with varied background in production scheduling, inventory control, testing and inspection, color matching and formulations, embossing, and as a sales representative. Engineering education. Willing to relocate. Box 3589, SPE Journal, 65 Prospect St., Stamford, Conn.

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Sales, sales promotion, research and development administration — personable, knowledgeable chemist, 34, phased out sales position small research company seeks challenge. Three years' experience expandable polystyrene. Background sales, sales promotion, commercial development, research, college teaching, agriculture. Go-getting soft-sell personality, experienced traveller, meticulous administrator. International interests, language facility. Box 3059, SPE Journal, 65 Prospect St., Stamford, Conn.

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Young chem major with practical experience in application and development of plastics available shortly. Excellent knowledge of vinyl and related compounds both extrusion and coating. Resing coating experience re: corrosion and electrical applications—minor formulation. Sales engineer experience in application of corrosion-proof materials. Age 38. Family. Willing to travel. Prefer Middle Atlantic states as base of operations. Reply: Box 3759, SPE Journal, 65 Prospect St., Stamford, Conn.

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Project leader with proven ability to push ideas and lead people to profits desires greater challenge and responsibility. Presently employed, thorough knowledge of the extrusion and calendering of vinyl products. B.S. Chemistry. Member A.C.S. and SPE. Prefer east coast location. $14,000 minimum. Resume on request.

Write Box 3159, SPE Journal, 65 Prospect St., Stamford, Conn.

POSITIONS OPEN

Organic Chemist

Chemist, organic—wonderful opportunity with young, but financially strong company just starting in cast acrylic sheets. The sky is the limit for person with acceptable qualifications. Box 3859, SPE Journal, 65 Prospect St., Stamford, Conn.

Ph.D.—Process Development

Expansion creates exciting opportunity for energetic process development engineer to work in a wide area of plastics process development.

Responsibilities would include development of automatic control instrumentation and new equipment to increase productivity, as well as work in cost reduction.

The man we seek should have a Ph.D. or equivalent in chemical engineering and possess the capability for creating and implementing new ideas. Experience in process engineering or development in thermoplastics or related materials is desirable.

This opening provides excellent growth potential for a self-starter. Good salary and liberal benefits. Please send resume to P. M. Townsend.

Celanese Corporation of America, 290 Ferry St., Newark, N. J .

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(*continued from page 519*)

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Report on Eighth International Meeting of ISO Technical Committee on Plastics Available Free to SPE Members

An annual report of ISO/TC-61 Committee on Plastics for 1958, is being offered free of charge to all interested SPE members. Larger quantities can be obtained for a small nominal charge. SPE is pleased to extend this service in order that members may receive a comprehensive report of this important meeting held in Washington, D. C. November 3-8, 1958.

This 68-page document contains information on all activities and events which took place during the meeting, as well as details on international plastics developments and progress in the establishment of plastics standards.

It carries the minutes of the eight ISO/TC-61 Working Groups and the first draft on five ISO Recommendations.

For your free copy, write to Society of Plastics Engineers, 65 Prospect Street, Stamford, Connecticut.

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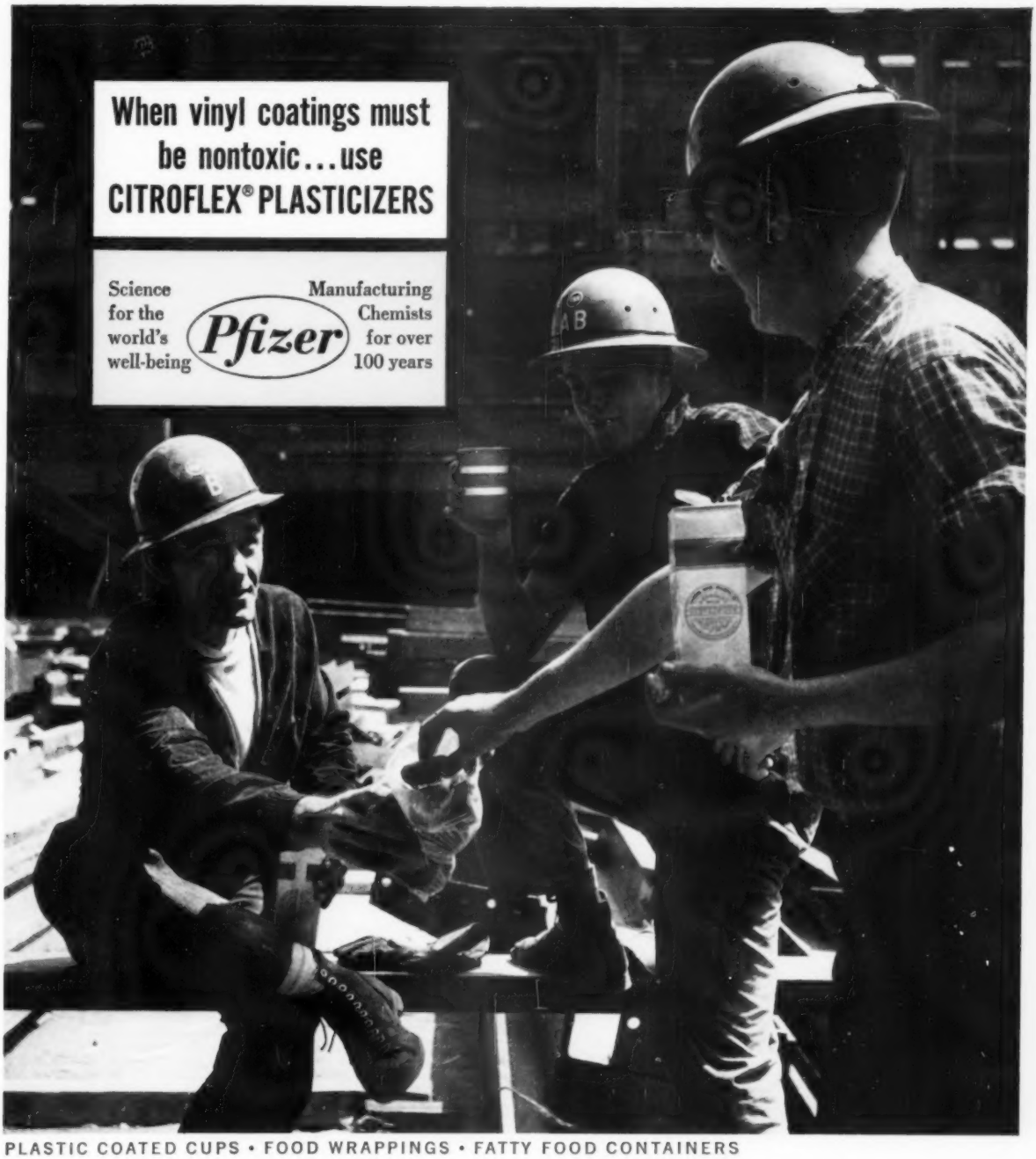
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